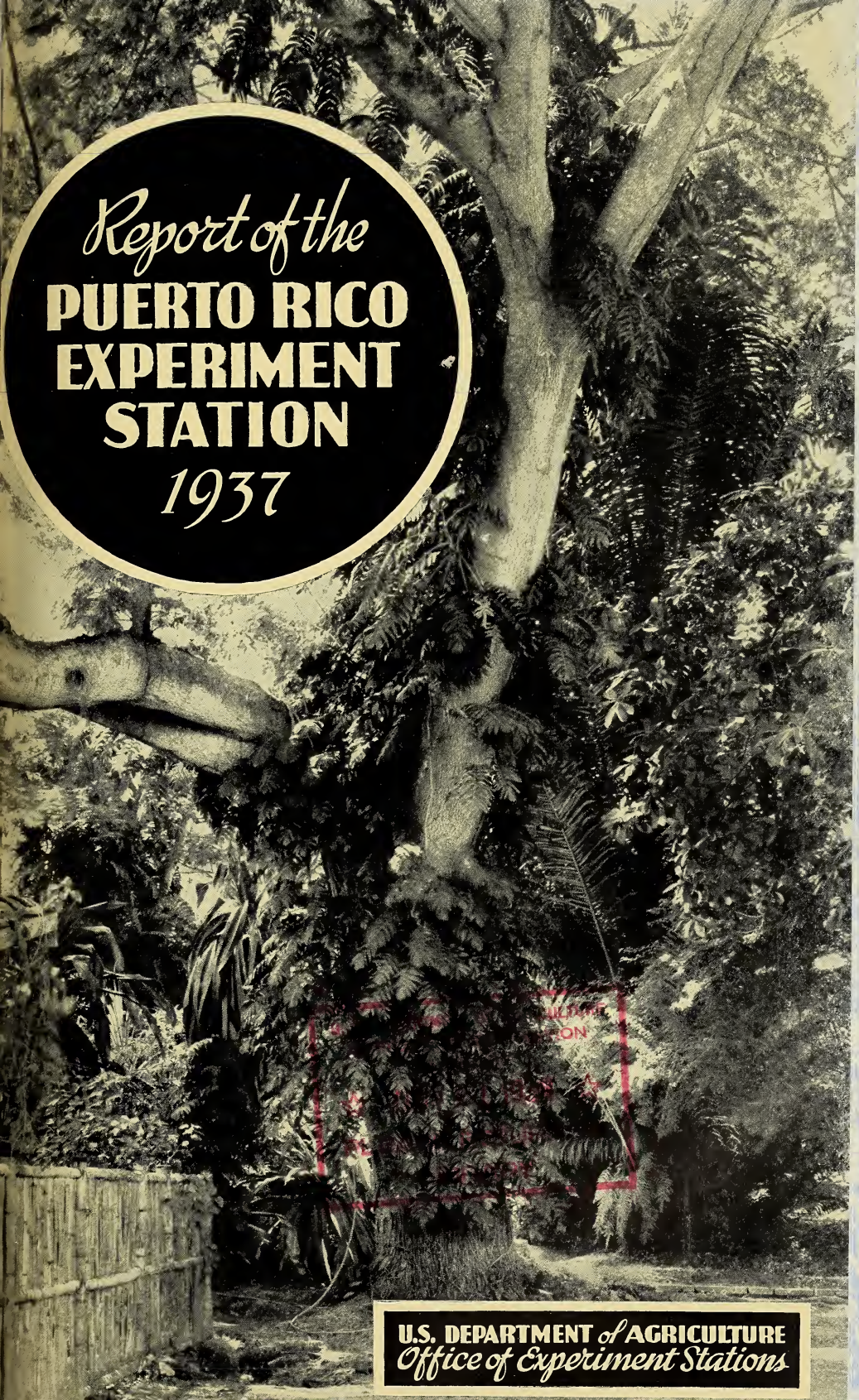
Report of the PUERTO RICO EXPERIMENT STATION 1937



U.S. DEPARTMENT of AGRICULTURE
Office of Experiment Stations

PUERTO RICO EXPERIMENT STATION
of the
UNITED STATES DEPARTMENT OF AGRICULTURE
MAYAGUEZ, PUERTO RICO

REPORT OF THE PUERTO RICO EXPERIMENT STATION 1937

Issued November 1938

UNITED STATES DEPARTMENT OF AGRICULTURE
OFFICE OF EXPERIMENT STATIONS

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PUERTO RICO EXPERIMENT STATION

Administered by the Office of Experiment Stations, United States Department of Agriculture

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On the front cover is reproduced a view in the oldest part of the plant-introduction gardens of the experiment station. The large tree in the center is *Enterolobium cyclocarpum*, a legume of Central America, the trunk of which is covered by the epiphytic vine *Monstera deliciosa*. The gardens afford an unusual opportunity for both local and visiting students of tropical botany, landscaping, and horticulture.

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CONTENTS

INTRODUCTION

Density of population necessitates crops of high value per acre.

As outlined in recent annual reports of this experiment station, the growing density of population in Puerto Rico increases in importance as a factor in its agricultural problems. The average area of productive land in the island is now less than one-half acre per person; the area of land per person available for agricultural production and hence income is, moreover, decreasing rapidly because of the steady increase in population from a relatively high birth rate. Since the island depends principally for its income upon the agricultural products of its soils, if average income per individual is to be sufficient to support reasonable standards of living, the necessity for devoting the land to crops of high value per acre is obvious.

Soil erosion has lessened areas of cultivated land.

As pointed out in the annual report of last year, erosion has caused the loss of the topsoils of large areas in the island, leaving the less productive subsoils with lower concentrations of plant nutrients upon which the income of the island must depend. The loss of the more fertile topsoils due to erosion is apparently one of the important factors in the shift of the population from rural to urban areas.

FIGURE 1.—A part of earliest plant-introduction gardens at the experiment station. The variegated screwpine, *Pandanus sanderi*, can be seen at the left; the large palms in the center are representatives of *Arenga saccharifera*, the sugar palm of the East Indies. The different textures of foliage are notable.

Hurricanes affect efficient land utilization.

The occurrence during the past 111 years of nine serious hurricanes, with an expectation of such a catastrophe once in every 12 years, has also been discussed previously. In general, orchard crops having an accumulated investment of several years suffer more serious financial losses from a hurricane than truck crops or field crops which, maturing in but a few months to a year, present relatively smaller investments.

The choice of crops aids in capitalizing on climate.

Attention has also been called to the fact that one of the great assets of the island is its climate, with comparatively uniform temperatures throughout the year and assurance of freedom from frosts during the winter months. It was pointed out that one of the most direct means of capitalizing on this asset was in the production of vegetable crops for marketing in the continental United States during the winter months. Puerto Rico is the only considerable area of the United States which can supply winter vegetable crops to the thickly populated eastern seaboard.

With an understanding of the foregoing basic factors, the development and direction of the activities of the experiment station for the benefit of Puerto Rican agriculture during the fiscal year ended June 30, 1937, can best be appreciated.

Some projects have value to continental agriculture.

The maintenance of a tropical plant-introduction garden, of value not only to Puerto Rico but to the continental United States, continues to be an important function of the experiment station. The earliest plant introductions are now 25 to 30 years old and form one of the most interesting and beautiful parts of the station grounds; a view in the oldest part of the introduction gardens is shown in figure 1.

In addition to the activities for insular agriculture the present report summarizes work upon projects for the benefit of agriculture in the continental United States. The climate of Puerto Rico, with its 12 months of continuous growing weather, makes possible the prosecution of projects which are impossible or considerably handicapped in the north where but 6 to 8 months of growing weather free from frosts may be depended upon. The investigation of tropical insecticidal plants, adaptation tests with seedling quinine trees, and midwinter breeding of some of the northern truck crops have been projects undertaken in previous years which have some value to the farmers and Government of the United States. This station has also been of service, aiding in the control of crop pests on the continent, by shipments of beneficial insects. The progress on these projects during the year under review is also recorded.

RELATION OF POPULATION TO LAND UTILIZATION IN PUERTO RICO

Acreage of land in farms has steadily decreased.

Since the preparation of the last annual report of this experiment station the census figures for Puerto Rico for the year 1935, enumerated and compiled by the Puerto Rico Reconstruction Administration, have become available. A tabulation is presented in table 1 which shows the number of farms, total areas in farms, and improved or arable land for the different census years from 1910 through to 1935.

TABLE 1.—*Decrease in farming areas in Puerto Rico from 1910 to 1935* [1]

Year	Farms	Total area in farms	Improved or arable land	Average arable land per farm
	Number	*Acres*	*Acres*	*Acres*
1910	58,371	2,085,162	1,570,304	26.90
1920	41,078	2,022,404	1,303,547	31.73
1930	52,965	1,979,474	1,222,284	23.08
1935	52,790	1,913,047	827,350	15.67
	Percent	*Percent*	*Percent*	*Percent*
Decrease, 1910–35	9.56	8.25	47.31	41.75
Decrease, 1930–35	.33	3.36	32.31	32.11

[1] Figures are from the U. S. Bureau of the Census.

It can be seen that the total area in farms has steadily decreased since the year 1910. The percentage decrease in area of farms was proportionately greater in the 5-year period 1930–35 than in the previous two decades.

Areas of improved land also decreased.

The census figures for improved or arable land are subject to slight explanation. For the years 1910, 1920, and 1930 statistics were

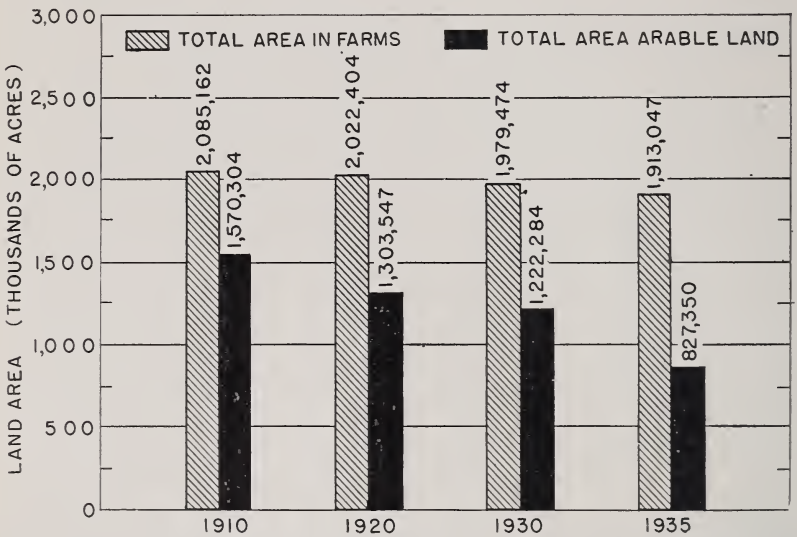

FIGURE 2.—Total area in farms and arable land in Puerto Rico in the census years 1910 to 1935, compiled from reports of the United States Bureau of the Census and the Census of Puerto Rico, 1935, Puerto Rico Reconstruction Administration, San Juan, P. R.

gathered for "improved land," defined as "all land regularly tilled or mowed; land in pastures that has been cleared or tilled; land lying fallow; land in gardens and orchards and land occupied by buildings, yards, and barnyards." For the census of 1935 this enumeration was modified to "tierra de cultivo," for which the best translation would be "arable land." The decrease in land under cultivation therefore might be due in part to slightly different conceptions of the enumerators concerning the nature of the information required.

The census enumeration "improved land" was used from 1910 to 1930; a reduced acreage of 22 percent was shown for the 20-year period.

The fact that "area in farms" decreased materially in the period 1930 to 1935 supports the acceptance of the figures for the decline in arable land during the same period, although the extent of the decline can be questioned.

The data contained in table 1 are shown somewhat more graphically in the bar chart in figure 2.

The proportionately greater decline in land areas in farms in the period from 1930 to 1935 is of course correlated with the economic depression during those years. However, it is obvious that since the steady decline began previous to 1930, factors other than the depression have been concerned in the lessened productive areas.

Soil erosion has been an important factor in decreased arable land.

A possible important factor has been the constant loss of the more fertile topsoils from hillside farm areas in the island, due to the intense rains and severe soil erosion. The topsoils have been completely lost from many of the hillside fields of much farm land, leaving subsoils which have become unproductive, and gradual abandonment of such fields has probably resulted.

Figure 2 also illustrates graphically the growing discrepancy between land in farms and land classed as arable and would indicate that lands at one time capable of production were being generally discarded and thrown into such low-value uses as woodlands or disuse. It seems apparent that some effective means should be developed for placing such idle or small-income land into intelligent production of crops of higher value per acre.

Arable land now averages less than one-half acre per person.

Using population figures for the 1935 census as a basis and the areas of arable land from the same census, but 0.48 acre of such land was available per person for the year 1935 as compared to 0.79 acre of improved land per person in 1930. With the increased population in the 2 years since 1935, the average area per person is even less at the present time.

These figures can best be understood when compared with figures of acreage of arable land per person for other countries and States of the United States. For convenience, some of the figures from the 1935 annual report are repeated briefly here: There were 8.26 acres of arable land per person in the Dominican Republic, 7.34 in Mexico, 3.97 in Spain, 1.31 in France, 1.68 in Italy, 3.24 in the State of Ohio, 8.63 in Mississippi, 5.36 in California, and 44.81 in Nevada. It should be borne in mind that in none of these countries or States is the population so largely dependent on agriculture for its income as in this island, where the income from industrial production is relatively small.

Idle land lessens average income per person in the island.

Inasmuch as a large proportion of the island income is dependent on agriculture, the foregoing figure of 0.48 acre of arable land averaged per person at the present time makes even more acute the obvious conclusion of previous reports that for a reasonable income per person and reasonable standards of living crops of high value per

acre are essential. And, conversely, the utilization of any large areas of land in the island for crops of low value per acre results in a lessened total income for the island, a lessened average income per person, and lowered standards of living. It is even more obvious that, if any areas of land capable of production are allowed to lie idle for a year, 6 months, 3 months, or even 2 weeks, they are lessening the total income of the island and the average income per person.

The studies of population in relation to land utilization have been made by Alfred N. Watson, biometrician and plant physiologist, and Atherton Lee, director of the station.

PREVENTION OF SOIL EROSION ESSENTIAL FOR ISLAND RECONSTRUCTION

Erosion has been proceeding rapidly from a geological viewpoint.

The geologists' viewpoints of soil formation, active processes, and destruction are fundamental and of great value to agriculture, although perhaps sometimes overlooked. A letter written in January 1934 by Howard A. Meyerhoff,[1] geologist of the Scientific Survey of Puerto Rico, to T. B. McClelland, former director of the station, has summarized the soil-erosion conditions in the island so trenchantly that it seems desirable to place a few of the paragraphs on record:

In Puerto Rico the soils are formed directly or indirectly by chemical weathering, or decomposition. The dominant soils are the clays, but there are some loams, and locally sandy varieties acquire importance. The process of weathering starts with granulation and spheroidal weathering in all the rocks except the limestones, and the product is a subsoil composed of partly decomposed mineral and rock grains. This subsoil undergoes further decomposition at the surface provided it is spared from erosion for a sufficient length of time, and in this fashion the tillable topsoil is produced. In general, decomposition proceeds rapidly from the geological viewpoint. New subsoils can be formed in 10 to 20 years; young cultivable soil in 100 to 200 years—longer for certain rock varieties, though I hasten to add these figures are merely rough estimates.

In general, the clay soils are tenacious, and the fact that they stick to the steep hillsides in spite of vigorous cultivation has evoked comment from many scientists. That they are undergoing steady removal by rainwash, however, is obvious enough from the color of the streams after every heavy shower; and the numerous slides and new gullies which appear during heavy rains reveal that the rate of erosion in the interior is precipitous. The sandier soils, on the other hand, wash with incredible speed wherever the relief is high, and the ravages of a single heavy rain are only too obvious in the districts where they are found.

The unwise destruction of vegetation in the deeply dissected interior during recent years is now being followed by rapid soil erosion, and I should estimate the rate of erosion as being approximately ten times as fast as soil formation. That is to say, a soil which required 200 years to develop from the underlying rocks can be removed completely in 20 to 22 years. The rate of removal, moreover, goes on at an increasing tempo because, as the older topsoil is washed away, the increasing coarseness of the younger soil beneath facilitates more effective and rapid wash; once the granular subsoil is reached, erosion is complete and almost immediate.

On certain types of rocks erosion to bedrock has already taken place in a few localities; in the older tobacco-raising districts the tenacious clay soils are in imminent danger of early depletion, and in the central portion of the island, especially in the Comerio, Cayey, Cidra, and Caguas sections, cultivation must soon cease unless immediate steps are taken to conserve the soil that remains. Indeed, only the fact that the virgin soil had developed over a period of thousands of years and was for this reason exceptionally thick, has enabled it to hold out this long under intense cultivation and tropical rain.

[1] Professor of geology and geography, Smith College, Northampton, Mass.

Unprotected hillside cornfields have lost best topsoils by erosion.

During the year a number of photographs of soil erosion resulting from different crops and different types of farming have accumulated. A few of these are presented to show some of the common and serious types of erosion and to indicate methods of cropping and agronomic practices which might minimize such erosion.

Figure 3 shows a typical cornfield in the interior hilly regions of Puerto Rico. Records are available and not unusual in the island of 1½ to 2 inches of rainfall occurring in 1 or 2 hours; during such rains in freshly tilled or cultivated cornfields, with loosened soils, it is almost impossible to prevent the loss of the topsoil by erosion. Figure 4, a closer view of a similar field, shows the sheet and gully erosion which have taken place within a few weeks after planting.

FIGURE 3.—A cornfield with slopes ranging between 30 to 40 percent, Aibonito-Cayey district. This field is representative of field-corn cultivation in a large part of the mountainous interior of the island. The loosening of the soil in the tillage preparatory to planting, as well as in the subsequent cultivation and weed control, renders the field highly susceptible to loss of the fertile topsoils by erosion during intense tropical rains.

It would seem that with the wide variety of agricultural products which can be grown in the Tropics and for which there are favorable protective tariffs, crops for hillside culture exist which would be fully as profitable as field corn and the erosion liability considerably less.

Figure 5 shows another view of the incipient sheet and gully erosion which have taken place in a young newly planted cornfield. On steep hillsides the susceptibility of corn cultivation to severe erosion of topsoils seems well established.

Figure 6 shows a hillside field planted to corn and in the center to tobacco. This figure shows that the corn rows are not planted in contours, but are planted vertically, a method conducive to rapid erosion.

FIGURE 4.—A close-up of a recently planted corn field in the Comerio district, showing both sheet erosion and the inception of gully erosion following the loosening of the soil in tillage operations for the planting of field corn on steep hillsides.

FIGURE 5.—A close-up of hillside land recently planted to field corn. Sheet erosion, followed by gullying while the soil is loosened by tillage and cultivation practices, can be seen. The increase in gullying in the lower part of the slope, even in the small area shown, is obvious.

Hillside cultivation of tobacco has been wasteful of fertile topsoils.

In the areas devoted to tobacco, shown in figure 6, some attempts have been made to dispose of run-off water by means of ditches, which have a value in minimizing the volume and velocity of hillside run-off water. However, such canals have been laid out at such an angle that the velocity of the run-off water would seem greater than is necessary. The distance between such run-off canals also seems too great for the degree of slope on which the field is planted.

Figure 6 also shows that although some of the brush cleared before tilling the field has been laid in contoured windrows, other windrows of such brush have been placed in vertical positions having little value in checking erosion. The cropping methods in figure 6 are fairly representative of much of the hillside cultivation of corn and tobacco in the interior sections of the island.

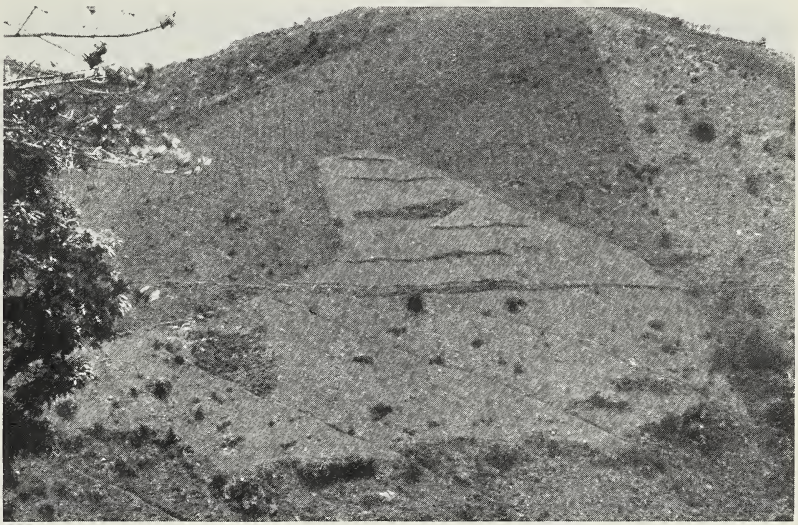

FIGURE 6.—A representative hillside field in the Aibonito-Cayey region, planted to corn and tobacco. Both the corn and tobacco, planted in vertical rows favoring soil erosion, can be noted. The diagonal canals in the tobacco area in the center of the field are common practice which lessens soil erosion to some extent. The volume and velocity of the run-off water could be decreased, however, by canals with closer spacing and less severe grades.

Regional planning could avoid wasteful crops on steep hillsides.

Tobacco is a crop similar to corn in that the soil must be tilled for each crop, and during which tillage, subsequent planting, cultivation, and weeding the soil is in a freshly stirred condition susceptible to soil erosion for considerable periods of time. In land-utilization planning it would seem as if there might be adequate areas of land of little or no slope in the island which would be less subject to erosion and which still could furnish the present island production of tobacco.

Figure 7 is a close-up of a tobacco field on a slope of 40 percent or more. The soil in this field is near the angle of repose, as indicated by the farmer's attempt to hold the soil in place with a casual piece of 2 by 4 lumber. Stirred soil in such a field is actually subject to loss of topsoil by gravity, even in the absence of rains.

Annual crops needing frequent tillage have increased erosion on steep hillsides.

In general, experience at the station during the year has shown that annual crops such as corn, tobacco, and cotton on steep hillsides result in wasteful soil erosion. It would seem that some island authority should be available to prevent such uneconomic, unproductive, and wasteful tillage as that shown in figure 7; such an authority is needed to provide regional planning for land utilization and crop practices in the island.

FIGURE 7.—A close-up of a tobacco field in the Cayey district, planted on slopes ranging between 40 and 50 percent. The slope in some places is greater than the angle of repose and erosion is resulting from gravity. The attempt of the farmer to check slide of the topsoil by means of the casually available piece of 2 by 4 can be noted. There are areas in the island better suited to tobacco production than such fields as this.

Severe erosion has followed root crops on steep hillsides.

Root crops, in the harvesting of which tubers or rhizomes have to be excavated, have also been found in experiment station practice to be wasteful from the standpoint of soil erosion on hillside fields. After such crops are harvested, the soil is left in a loosened, uneven condition highly susceptible to erosion when exposed to hard rains. In general, using the land for permanent bush crops, small-tree crops, or perennials, notably some of the grass crops, which do not need to be replanted each year or can be ratooned, has been better practice in minimizing soil erosion on hillsides than the use of root crops, corn, cotton, or tobacco.

Broad bench terraces have been used for winter vegetable crops on steep hillsides.

During the year a number of broad bench terraces as distinguished from the narrow, canalled terraces pictured in the last annual report were constructed. Whereas the narrower terraces were suited only for such crops as vanilla, the width of the new type of terrace permitted

FIGURE 8.—One of the hillside areas at the experiment station, formerly waste land and now in bench terraces. Terraces above these have produced excellent crops of winter vegetables, an area of cucumbers maturing in January yielding a crop with a gross value of more than $900 per acre, calculated on New York prices.

FIGURE 9.—Bench terraces planted in fertilizer experiments with sweet peppers and summer squashes in March. Papaya trees, which require good drainage, can be seen in luxuriant growth on the outer edge of the topmost terrace.

cultivation of such vegetable crops as cucumbers, tomatoes, peppers, and summer squash.

Figures 8 and 9 show broad bench terraces at the experiment station, on slopes of 30 to 50 percent, which have minimized soil erosion and made the land available for crops of high value per acre.

High-value crops were necessary to yield return on increased investment in terraced land.

The labor employed in constructing such terraces has cost several hundred dollars per cultivable acre, and the interested personnel and cooperators have from time to time felt doubtful of the practicability of these broad bench terraces. Discussion has developed the conclusion that if crops can be grown on the terraces which will return net yields of at least 6 to 10 percent on the total investment in land and improvements, the labor costs are justified. Such broad bench terraces, it has been concluded, are entirely uneconomic for the production of crops of low gross value per acre; however, when crops have been grown which capitalized on the climate, such as high-value winter vegetable crops, adequate income was possible to yield good returns on the terracing costs, when considered as a capital investment. The steep hillsides used for terracing have been for the most part unproductive, in little or no demand, and the cost per acre low; the cost of the labor in terrace construction has been considerably more than the original value of the land.

It has been concluded that an essential for making expenditures for bench terraces profitable is the selection of a crop adapted to the climate and soil environment and one which will be aided rather than handicapped by such environment.

As density of population increases greater expenditures are reasonable for productive land.

Density of population has also been considered a salient factor. In Nevada, for example, with an average of less than one person per square mile and an average of almost 45 acres of arable land per person, such terraces are clearly uneconomic at the present time. In an island such as Puerto Rico, however, with a density of population of 501 people per square mile, less than one-half acre of arable land per person, and income almost exclusively dependent on agriculture, the value of such improved land may be sufficiently great to pay for the cost of terracing. It has seemed the function of agricultural research agencies to attempt to determine within reasonable limits the point at which terracing has reasonable chances of returning an income on the investment. Particularly has this seemed an urgent field of investigation in this region which, while dependent on agriculture, has inadequate land resources and an ever increasing population.

The bench terraces in an island of surplus unemployed labor and low capital assets have seemed to have possibilities for converting such idle man power into greater capital wealth and income possibilities.

The population-per-acre curves have been impressive in indicating the urgency of making more and more island land productive. With such studies in mind, the conclusion has seemed logical that if bench terraces are not yet an economic investment, the increasing population will sooner or later increase the value of productive land to a point at which such terraces will be economic.

Narrow, canalled terraces were constructed more cheaply than broad benches.

The narrow, canalled terraces first developed for vanilla culture during the previous year were tried out this year for papayas and seem to be well adapted for such use. The returns from both vanilla and

papayas seemed to give reasonable chances of good returns on the lesser investment in narrow, canalled terraces. Figure 10 shows a hillside of 30- to 45-percent slopes upon which this cheaper type of terrace has been constructed. The terraces have been planted to trees of *Erythrina berteroana*, a support tree used for vanilla; the support trees are now sufficiently advanced for planting the vanilla seed pieces.

Mangum terraces are less expensive than bench terraces.

Because the broad bench terraces on steep hillsides are somewhat spectacular from a distance, they have attracted much more attention than other erosion-control practices which have been considerably cheaper and have greater possibilities for adoption over large areas of land. From the experience of the experiment station during the year it seemed that contour canals and mangum terraces have greater immediate possibilities over large areas than broad bench terraces.

FIGURE 10.—A hillside of slopes of 30 to 45 percent at the experiment station, upon which the cheaper type of narrow, canalled terraces has been constructed. The terraces are planted to the leguminous tree, *Erythrina berteroana*, which is used as a support and shade for vanilla vines.

Additional areas of mangum terraces have been constructed; such terraces have been made up considerably cheaper than the bench terraces and have been used for a wider variety of crops. Such crops as cotton, cucumbers, summer squashes, and even such root crops as ñames and sweetpotatoes were successfully produced on mangum terraces without serious losses of soil from erosion. In considering the utilization of land by mangum terraces, first cost of the land has been considered; the ultimate cost of slightly sloping land, well protected from erosion by mangum terraces, has not been greatly different from that of low-value land on steep slopes worked into narrow, canalled terraces.

Different methods of planting the areas between mangum terraces have been tried.

Different systems of handling soil between mangum terraces have been tried in the upper Las Mesas fields. While little soil was lost from the field, during some of the hardest rains there has been some movement of the soil from the areas between the terraces down into the terrace

channels. This movement of soil and its deposition in the channels of the terraces has been found to vary considerably with the manner in which the area was planted. Between many terraces the soil was not level. With flat or level planting, during a hard rain, water concentrated in some of the low places and considerable soil was washed down into the terrace channels. With ridge planting in which the ridges followed the course of the upper terrace the water concentrated in the low areas and broke through the ridges, and the subsequent washing of soil down into the terrace channel was even more extensive than with level planting.

Level planting in which the rows were made at right angles to the terraces with shallow furrows between each row prevented the concentration of water in the low places and only a small volume of water flowed down each row. While this method gave better control to the soil movement than the ridges and level planting without the furrows, there was still some movement of soil due to the velocity of the water flow.

Ridge planting and level planting with shallow furrows between rows, in which the rows were made diagonally across the slope at an angle just sufficient to allow the water to flow between each row without breaking over into the next row below, gave the best results. These two methods have so effectively reduced the velocity of flow and the concentration of water at any one point that there has been little or no movement of soil down into the terrace channels.

Contour canals lessened erosion in hillside bush and small-tree crops.

Soil erosion on steep hillsides was minimized in considerable areas planted to small-tree crops by the construction of contour canals, which lessened the volume and velocity of the run-off water. Such contour canals have been much cheaper to construct than bench terraces or even mangum terraces. They also have an advantage in facilitating ingress and egress to and from the plantings on steep hillsides. An ylang-ylang orchard protected by such contour canals from injury by large volumes and velocities of run-off water is shown in figure 11.

Crop selection for hillside plantings can minimize erosion.

During the year's experience it has become evident that the selection of suitable crops for hillside planting has been a basic factor in economical lessening of soil erosion, probably equally as much so as engineering practices. Tree crops which do not need much soil cultivation, such as mangoes, some of the palm-tree crops, bay oil, and ylang-ylang, are now being tried to determine their profit possibilities and to avoid serious erosion.

In the annual report for the previous year, soil erosion was shown in overgrazed hillside pastures; the condition has been observed commonly in the island. During the year such forage crops as Guatemala grass, elephant grass, and Uba cane have been grown on steep hillsides, previously unproductive. Such grasses have had a beneficial effect in checking erosion and can be cut back and ratooned with little cultivation or loosening of the soil. Such low-value grass crops have possibilities of paying returns on low-value, previously unproductive, steep hillside land.

Another grass crop which has checked erosion and has profit possibilities is lemon grass, *Cymbopogon citratus*, from which lemon oil used

in perfumes is obtained. This grass has been grown on low-value hillside land at the experiment station; lemon oil has a moderate protective tariff.

Search is continuing for further crops which will aid in minimizing erosion for hillside cultivation which have profit possibilities.

FIGURE 11.—Two-year-old ylang-ylang orchard on a slope of 30 to 50 percent showing a contour canal to intercept and lessen the volume and velocity of run-off water. The grassed-in character of the canal strengthens its walls and lessens erosion.

Earth dams for flood control have reclaimed land.

In the annual report of last year a description was given of an earth dam to impound water for irrigation and to lessen freshet damage. The two dams now in service at the station have been maintained during the rainy season at levels well below the overflow outlet. This has resulted in controlled flows of water down the lower valleys in

periods of heaviest rain as well as during nonrainy periods and has resulted in few floods in such lower valley fields. Considerable reclamation has been obtained in fields in which flood damage was previously too great to risk in high-value crops. There are thousands of valleys in the island in which such earth dams could be advantageously built to impound water for irrigation for small areas and also to make the land safer for intensive cultivation in the valuable alluvial areas below such dams.

The soil-conservation work at the beginning of the year was under the supervision of George J. Burkhardt, associate agricultural engineer. During the year the Soil Conservation Service of the Department has been quartered at the experiment station, and the work previously carried on by the station has gradually been turned over to that Service. George L. Crawford has been in charge of the work of the Soil Conservation Service, which has successfully extended and amplified the soil-conservation studies and demonstrations of the station.

VANILLA PRODUCTION AND PROCESSING STUDIES

Experiments were conducted to improve germination of seed pieces.

Continuing the projects which were recorded in the last annual report, field experiments in the present year were concerned largely with methods of germinating vanilla seed pieces.

Commercial vanilla plantings are made by means of vegetative cuttings rather than by true seeds. There have been some expensive failures in commercial plantings due to poor germination of cuttings; the following simple experiments were undertaken in September 1936 in an effort to determine the factors influencing germination and to make available to planters more definite information concerning such factors.

EXPERIMENT ON SEED-PIECE POSITION

Eight-node cuttings of uniform character were used.

In the first experiment seed-piece cuttings were compared as to their germination and subsequent growth when placed in different positions. A record was made of the germination of both root eyes and axillary shoot buds of such cuttings when planted prone, in comparison with seed pieces planted in an inclined position, vertically, and suspended above the mulch in a vertical position.

All seed-piece cuttings in this experiment were taken from healthy vines of vigorous vegetative habit which had never been pollinated and consequently never had produced a crop of beans. Each cutting contained eight nodes with the leaves removed from the lowermost six nodes. Prior to planting all cuttings were hung on supports, free from the ground for 3 days, to permit the formation of callus tissue on the cut surfaces and thus reduce infection with rot organisms.

There were 10 replicated plats of each series of seed pieces.

Two hundred of the cuttings, selected for uniformity of diameter and length, were divided into four groups of 50 cuttings each. The cuttings of the first group, treatment *A*, were laid horizontally for their whole length on the mulch-covered ground and curved around the base of upright stakes. The cuttings of the second group, treatment *B*, were laid horizontally on the ground for the length of the lowermost six nodes, while the seventh and eighth nodes with leaves

attached were turned upward and tied with raffia to support stakes that had been placed in the ground at an angle of 45°. The cuttings in the third group, treatment *C*, were planted in the same manner as those of the second group except that the support stakes were set in the ground vertically rather than at an angle of 45°. In the fourth group, treatment *D*, the vanilla cuttings were tied with raffia for their entire length to vertical stakes in such a way that the lower ends of the cuttings hung approximately 2 inches above the mulched surface of the ground. All parts of the cuttings of all groups, namely, *A*, *B*, and *C*, lying on the mulched surface, were covered with a few handfuls of dried grass to preserve moisture and favor germination.

Uniform shade was provided for all plants by black muslin stretched on a frame 7 feet above the experimental plants.

The support stakes in each series of cuttings were placed 17 inches apart in rows. Each series of cuttings of a given treatment group was divided into 10 plats of five cuttings each. Thus there were 10 replicated, randomized plats of each type of seed-piece treatment.

Seed pieces in prone position showed poorest root formation.

Records were taken of the germination of root eyes at approximately 7-day intervals from October 6 to December 29. The tabulation of such records, somewhat consolidated, is shown in table 2.

TABLE 2.—*Roots formed on seed-piece cuttings of vanilla in an experiment to test the comparative effect on root formation produced by planting in four specified positions* [1]

[Plantings were made on Sept. 25, 1936, 50 cuttings for each treatment or position]

Treatment symbol	Planting position	Cuttings showing root formation—							
		Oct. 6		Oct. 20		Nov. 4		Nov. 17	
		Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
A	Prone	0	0	27	54	28	56	26	52
B	Inclined	3	6	33	66	36	72	37	74
C	Vertical	3	6	35	70	41	82	46	92
D	Suspended	8	16	20	40	31	62	38	76
Total		14		115		136		147	

Treatment symbol	Planting position	Cuttings showing root formation—					
		Dec. 1		Dec. 15		Dec. 29	
		Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
A	Prone	25	50	21	42	21	42
B	Inclined	37	74	36	72	36	72
C	Vertical	45	90	41	82	37	74
D	Suspended	36	72	36	72	41	82
Total		143		134		135	

[1] Records for the alternating weeks Oct. 14 and 27, Nov. 10 and 24, and Dec. 8 and 22 are omitted from the above tabulation for economy of space.

The foregoing tabulation shows that the seed pieces which were placed horizontally or prone on the ground for their whole length showed poorer root formation after the sixth week of the experiment than the seed pieces that were planted in other positions. The results are statistically significant and have considerable economic importance.

The epiphytic nature of vanilla has apparently had some influence on the root reactions in these experiments.

The seed pieces which were placed in an inclined position were consistently poorer in root formation than those planted in an erect position, but such differences were not so conclusive as those that existed between the prone seed pieces and those placed vertically.

As the experiment advanced, the dry season normal to western Puerto Rico also advanced, being unfavorable to aerial roots; this is the most reasonable explanation for the decreased numbers of roots recorded for all position treatments toward the close of the experiment.

Figure 12 shows graphically the results recorded in table 2.

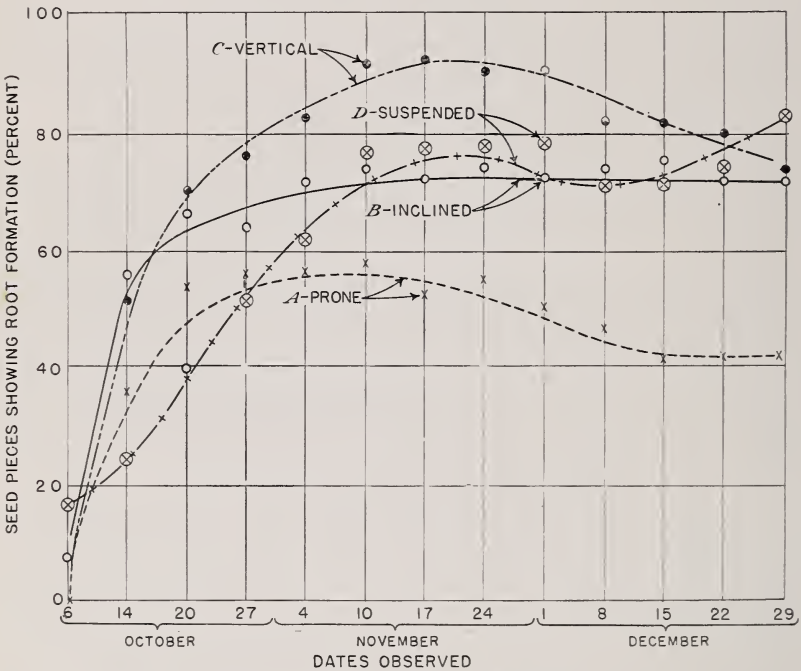

FIGURE 12.—Percentages of vanilla seed pieces showing root germination when placed in four different planting positions during 13 weeks following planting.

Although the seed pieces which were suspended above the mulch showed fairly good root germination, subsequent to the last date recorded above, the cuttings shriveled to a considerable extent and then failed notably in comparison with seed pieces planted vertically in treatment *C*—i. e., in which the lower part of the cutting was laid on the mulch and the other part tied to a vertical stake.

Cuttings planted in vertical position gave best axillary bud germination.

Records were also taken of the number of shoot buds which germinated in the period from time of planting, September 25 to March 23, and these are presented in table 3. In this connection it should be mentioned that the months of December, January, February, and

March constitute the dry season in Mayaguez and that unusually dry weather was experienced which was unfavorable for shoot growth in vanilla during the above period of this experiment.

TABLE 3.—*Eight-node seed-piece cuttings of Vanilla fragrans in series of different planting positions, showing germination of axillary-shoot buds and extent of subsequent growth 6 months after planting on Sept. 25, 1936*

[50 cuttings for each position]

Treatment symbol	Planting position	Cuttings showing axillary bud germination Mar. 23, 1937		Length of stem growth	Average growth per cutting planted
		Number	*Percent*	*Inches*	*Inches*
A	Prone	12	24	210	4.20
B	Inclined	16	32	540	10.80
C	Vertical	18	36	291	5.82
D	Suspended	1	2	15	.30

From table 3 it can be seen that the cuttings which were suspended with their lower tips not reaching the ground, treatment *D*, gave the poorest germination of axillary-shoot buds and subsequent growth. The cuttings which were planted in a prone position, treatment *A*, were considerably better than those suspended entirely above the ground, but germination and growth were still relatively poor. The cuttings which were planted with six nodes covered in the mulch and two nodes in an inclined position on the supports, treatment *B*, gave the best growth per seed piece. However, the percentage germination of axillary buds was excelled by the cuttings planted with uppermost two nodes in a vertical position, treatment *C*. These results are shown graphically in figure 13.

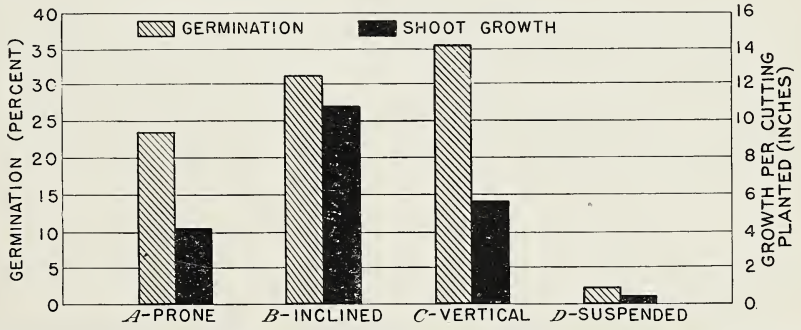

FIGURE 13.—Germination and subsequent growth of axillary-shoot buds in planting-position experiment in vanilla.

Uppermost nodes gave best germination of axillary buds.

Before considering the planting position which resulted in the best longitudinal shoot growth, it is interesting to observe which nodes on the cuttings gave the best germination. In table 4 are recorded the number of axillary eyes germinating in the different node positions on the cuttings.

TABLE 4.—*Distribution of axillary-bud germination according to position on the seed-piece cutting on Mar. 23, 1937*

[100 nodes planted for each position]

Treatment symbol	Planting position	Distribution of axillary-bud germination in node No.—								Total nodes germinated	
		1	2	3	4	5	6	7	8		
										Number	*Percent*
A	Prone	0	3	1	1	2	3	0	2	12	3.00
B	Inclined	1	1	0	1	2	3	5	3	16	4.00
C	Vertical	0	1	0	1	3	2	8	3	18	4.50
D	Suspended	0	1	0	0	0	0	0	0	1	.25

It can be seen that when the cuttings were planted entirely in a horizontal or prone position, there was no marked superiority of axillary-bud germination in any part of the seed piece. However, in treatments *B* and *C* where the cuttings were planted with their upper parts inclined or vertical, the axillary-bud germination was best at the seventh node, which would be the one second from the top. Where the cuttings were suspended in the air the lowermost nodes only gave axillary-bud germination, which possibly would be explained by the better moisture conditions near the mulched soil.

Cuttings in inclined position produced best longitudinal growth.

Although the cuttings that were placed in an inclined position did not show the best axillary-bud germination, it can be seen in table 3 that they produced much the best longitudinal growth with almost double the length recorded for the seed pieces planted in the next best or vertical position. This stem growth is even more significant when compared with that of the seed pieces planted in a prone position and those suspended above the ground.

The data recorded in tables 2, 3, and 4 indicate that the position in which vanilla seed pieces are planted is highly important for good germination and subsequent growth. For convenience it should be restated that the planting method which gave a high percentage of bud germination and much the best shoot growth consisted in placing eight-node cuttings with the lower six nodes covered in a mulch bed and the upper two nodes above ground in an inclined position.

EXPERIMENT ON SEED-PIECE DEFOLIATION

Nondefoliated seed pieces were compared with partially and completely defoliated seed pieces.

A second experiment planted September 25 and conducted contemporaneously with the planting-position experiment just recorded was organized for the purpose of comparing the effects of three types of defoliation of vanilla seed-piece cuttings upon root and shoot germination.

The cuttings were secured from the same source and treated in the same manner as for the planting experiment described above. In series *X*, 50 eight-node cuttings were included with all leaves left attached. In series *Y*, 50 cuttings were completely defoliated. In series *Z*, also consisting of 50 cuttings, all leaves were removed with the exception of the uppermost two on each seed piece. In planting, the two topmost nodes of all cuttings were attached with raffia to

supports set vertically in the ground and 17 inches apart; the lower six nodes of each cutting were simply laid on mulch and covered with a handful of dried grass, the basal tip of the cutting having been left exposed in all cases.

Each series of 50 cuttings was divided into 10 different lots which were planted in 10 replicated randomized plats of five cuttings each; all 30 resulting plats received uniform shade and care.

Nondefoliated vanilla seed pieces gave significantly superior root formation.

Records of germination of root eyes were taken at approximately 7-day intervals from October 6 to December 29, 1936, inclusive, and are shown, minus those for alternate weeks, in table 5.

TABLE 5.—*Vanilla cuttings with different degrees of defoliation showing root formation* [1]

[50 cuttings of each treatment planted Sept. 25, 1936]

Symbol	Defoliation treatment	Cuttings showing root formation							
		Oct. 6		Oct. 20		Nov. 4		Nov. 17	
		Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
X	All leaves attached	5	10	44	88	44	88	40	80
Y	All leaves removed	2	4	21	42	24	48	24	48
Z	All leaves removed except topmost two.	2	4	29	58	38	76	30	60
Total		9		94		106		94	

Symbol	Defoliation treatment	Cuttings showing root formation					
		Dec. 1		Dec. 15		Dec. 29	
		Number	*Percent*	*Number*	*Percent*	*Number*	*Percent*
X	All leaves attached	38	76	39	78	34	68
Y	All leaves removed	18	36	16	32	11	22
Z	All leaves removed except topmost two.	29	58	27	54	26	52
Total		85		82		71	

[1] The records for root germination made during alternate weeks on Oct. 14 and 27, Nov. 10 and 24, and Dec. 8 and 22 are omitted for purposes of economy of space.

It had been our previous impression that by defoliating the cuttings to some extent, transpiration of moisture from the cuttings would be reduced and better germination would therefore result. The results recorded in table 5 show clearly that such is not the case. The best root germination was obtained in treatment *X* where all leaves were left attached to the seed piece; the difference in root germination resulting from this treatment and that from treatment *Y* in which the seed pieces were completely defoliated was highly significant. Also the root germination of the seed pieces in which the two uppermost leaves were left attached, treatment *Z*, was significantly superior to that of the seed pieces which were completely defoliated. Although the root germination of the seed pieces in which all leaves were left attached was decidedly superior to the germination of those in which only the two uppermost leaves were left attached, such difference was not statistically significant.

Defoliation causes great loss of nutrients but lessens transpiration only slightly.

It seems apparent that the foregoing results are completely logical from a physiological viewpoint. Apparently the vanilla plant, being an epiphyte, has a leaf structure of such a type that loss of moisture by transpiration is slight. Thus when the leaves are removed from vanilla seed pieces, the loss of moisture is reduced but slightly, and on the other hand considerable reserve food materials are lost. The foregoing results seem highly important for consideration in planting in commercial vanilla projects.

The middle nodes of seed cuttings gave best root formation.

The numbers of roots formed at each node position were also recorded in the foregoing experiment and are presented in detail in table 6.

TABLE 6.—*Root formation at each node of vanilla cuttings having different degrees of defoliation* [1]

[50 eight-node cuttings planted for each treatment]

Treatment symbol	Defoliation treatment	Distribution of root formation in node No.—								Total
		1	2	3	4	5	6	7	8	
X	All leaves attached	10	13	19	18	27	18	2	0	107
Y	All leaves removed	7	4	6	4	8	3	0	2	34
Z	All leaves removed except topmost two	2	10	7	11	7	15	5	8	65
Total		19	27	32	33	42	36	7	10	206

[1] Experiment planted Sept. 25; data recorded Nov. 4, 1936.

It is interesting to see that in this experiment the best root formation in all treatments was obtained from the nodes in the middle of the seed piece.

Nondefoliated cuttings yielded best stem and leaf growth.

In addition to germination of root eyes, the germination of axillary shoot buds was likewise recorded, and the extent of subsequent elongation of such shoots. The results are shown in table 7, which follows:

TABLE 7.—*Eight-node seed-piece cuttings of Vanilla fragrans having different degrees of defoliation showing axillary-bud germination and subsequent growth*

[50 cuttings planted for each treatment, Sept. 25, 1936]

Treatment symbol	Defoliation treatment	Cuttings showing axillary-bud germination, Mar. 23, 1937		Length of stem growth	Average stem growth per cutting planted
		Number	*Percent*	*Inches*	*Inches*
X	All leaves attached	19	38	495	9.90
Y	All leaves removed	3	6	45	.90
Z	All leaves removed except topmost two	13	26	401	8.02

Table 7 shows that the cuttings in which all leaves were left attached to the seed pieces gave much better germination than the series of cuttings in which all leaves were cut off or in the series in which all leaves were cut off except those at the topmost two nodes. The experimental differences were statistically significant. It can be seen also that the length of stem growth was considerably better where all leaves were left attached to the seed piece. The longitudinal growth of the cuttings in which all leaves were cut off was less than one-tenth of the growth in the series in which all leaves were left attached to the seed piece. The data recorded in table 7 are shown more graphically in figure 14.

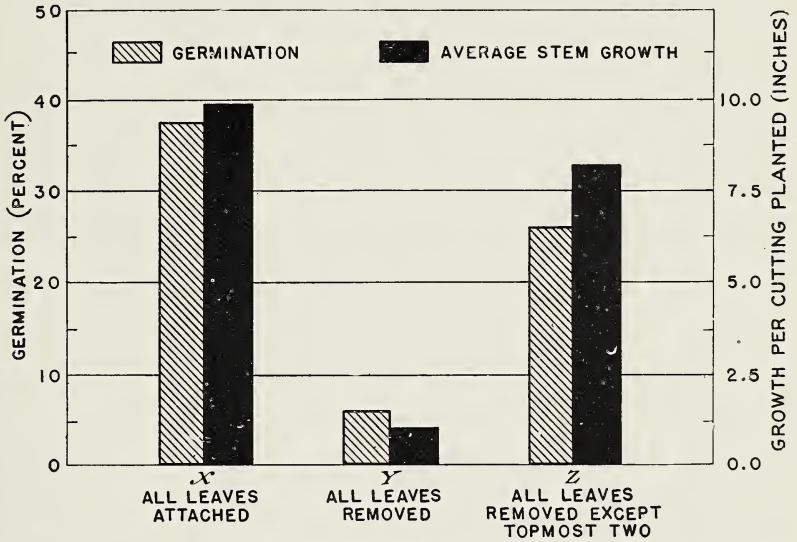

FIGURE 14.—Comparative axial-bud germination and subsequent shoot growth in vanilla seed pieces with different degrees of defoliation.

Uppermost nodes of seed pieces gave best axillary-bud germination.

In table 8 are recorded the numbers of germinations on the seed pieces in each defoliation treatment series according to the position of the axillary bud on the seed piece.

TABLE 8.—*Distribution of germination of axillary buds on eight-node cuttings of Vanilla fragrans 6 months after planting on September 25, 1936*

[400 nodes planted for each treatment]

Treatment symbol	Defoliation treatment	Distribution of axillary-bud germination in node No.—								Total	Percent
		1	2	3	4	5	6	7	8		
X	All leaves attached	0	1	0	2	3	2	4	9	21	5.25
Y	All leaves removed	1	0	0	0	0	0	2	0	3	.75
Z	All leaves removed except topmost two.	0	0	0	0	2	2	2	7	13	3.25

Table 8 shows that the shoot eyes at the topmost nodes gave the most germination. Also the germination of the cuttings as based upon the growth of individual eyes was much better for the series in which all leaves were left attached to the seed pieces than where partial defoliation and complete defoliation were practiced.

Although at the outset of this work the questions of defoliation and planting position of vanilla cuttings seemed of somewhat minor importance, it can be seen from the foregoing results that on the contrary they are decidedly matters of major importance in planting areas for commercial vanilla production.

These experiments were planned by Lee and Pennington, executed by Pennington, and analyzed statistically by Watson.

CROSS POLLINATIONS WITH VANILLA SPECIES

Vanilla barbellata did not hybridize easily.

During the latter part of June 1936, hybridization of *Vanilla* species was attempted. When flowers of *V. barbellata* were pollinated from the anthers of *V. fragrans*, seven such pollinations set fruit and reached a length of about 4 inches. However, abscission and gradual dropping of the resulting fruits occurred until on December 7 all such pods had dropped. Flowers of *V. barbellata* were also pollinated with pollen of *V. pompona*; four of the five flowers which were thus pollinated formed pods, but they all later abscised and dropped.

Five flowers of *V. fragrans* were pollinated from the anthers of *V. barbellata*. Two of the five flowers formed pods, but these abscised before reaching maturity. Pods resulting from chance self-pollinations on vines of *V. barbellata* in the near vicinity remained attached and matured.

These first pollination studies indicate, therefore, that hybridization of *V. barbellata* is difficult, at least with *V. fragrans* and *V. pompona*.

Vanilla fragans flowers matured fruits when crossed with V. pompona.

Flowers of *V. fragrans* when crossed with pollen from *V. pompona* formed fruits which reached maturity. The reciprocal cross also formed mature fruits.

Attempts to germinate seeds from these crosses have been unsuccessful to date. However, seeds from fruits of both species from naturally pollinated as well as artificially pollinated flowers failed to germinate, so that the failure of the seeds of the crosses to grow may have been due to germination methods rather than to viability of seed.

VANILLA BEAN PROCESSING STUDIES

Several new methods of processing vanilla beans were successful.

Experiments in the processing of vanilla beans undertaken in the winter of 1936 came to a conclusion during the past fiscal year. In this experiment different methods of what has been called "killing" were compared with exposure to hot water at 80° C. as the control or standard killing practice. The treatments used, time consumed, and period necessary for the completion of curing, together with losses in weights, vanillin content, and aroma ratings are presented in table 9, which follows.

TABLE 9.—*Results of various experimental treatments used in the processing of vanilla beans*

Nature of treatment	Killing time	Sweating	Final drying	Total curing	Loss in weight	Split beans	Vanillin content	Aroma
		Hours	*Days*	*Days*	*Percent*	*Percent*	*Percent*	
Water at 80° C.	1½ minutes	100	17	21	62.2	24.1	1.785	Poor.
1–1,000 potassium permanganate.	do	100	15	19	65.8	21.2	1.680	Neutral.
1–100 manganese sulphate.	do	100	17	21	61.6	16.2	1.015	Do.
1–500 manganese sulphate.	do	100	15	19	65.2	27.4	1.180	Do.
1–1,000 manganese sulphate.	do	100	15	19	68.2	19.1	1.125	Do.
Steam chamber	22 hours	100	10	15	58.8	33.3	.040	Woody and moldy odor.
Do	20 hours	81	9	13	63.1	25.3	.025	Do.
Do	18 hours	81	9	13	62.5	21.1	.030	Do.
Do	24 hours	81	10	14	60.9	20.5	.010	Do.
Do	26 hours	81	10	14	64.2	12.5	.025	Do.
Ethylene gas	38 hours	100	12	20	60.0	57.0	2.060	Fair to good.
Do	62 hours	100	12	20	62.2	63.9	2.025	Do.
Do	86 hours	100	14	22	57.0	80.4	2.115	Do.
Sun killed	6 hours	101	9	[1] 23	56.7	79.1	2.150	Fair.
Quick cold at −1° C.	5 minutes	103	6	[1] 20	50.5	46.5	2.040	Do.
Ultraviolet rays	16 hours	95	15	19	56.6	37.0	1.695	Do.

[1] Due to the exigencies of the work the sun-killed and quick-cold lots had lain in the shade on a shelf for 10 days previous to the application of the killing treatment. As a natural ripening process had inevitably been active during this period, comparisons of these lots with others should be made with that circumstance in mind.

Ethylene gas hastened formation of vanillin crystals.

Numerous details of the methods used and final results secured cannot be shown in a table such as the foregoing but may be briefly recorded as follows: The vanillin crystals formed much more quickly on the ethylene-treated beans than in any of the other treatments. No decided differences could be observed in the quality of the beans resulting from any of the three different exposures to the ethylene gas, and thus the shortest exposure was the most economical and preferable. Immediately after the processing was completed the vanillin crystals were in much greater abundance on the pericarps of the beans treated with ethylene gas than with any of the other treatments. However, 6 months after the processing was completed the crystals had to a considerable extent disappeared from the beans in the ethylene-gas treatments, and the beans treated with hot water then had the greatest number of crystals, but probably not in such great quantities as had been present on the ethylene-treated beans at the time of their maximum vanillin coating.

As shown in table 9, the beans treated by direct exposure to the sun had the greatest concentration of vanillin at the time of analysis, closely followed by the beans treated with ethylene gas. The beans treated with oxidizing agents had notably low vanillin content. The beans treated with ethylene gas and the sun-killed beans showed the greatest amount of splitting. Although split beans bring lower prices than whole beans of corresponding grades, the split beans from both the ethylene and sun-killed treatments yielded satisfactory extracts.

The beans treated with quick cold showed the smallest loss in weight during curing, a decided advantage to the processor if at time of sale the moisture content of the cured beans is not a factor entering into prices. The vanillin content of these beans was also favorable.

The beans treated in the steam chamber had a poor aroma, the typical vanilla fragrance being blended to some extent with a woody, dank, foreign odor. This lot of beans became moldy. The aroma of the ethylene-treated beans was considered by the judging committee better than that of the beans with the standard treatment of exposure to hot water or the cold treatment. None of the treatments of beans showed any evidences of piperonal or anisic compounds, which give unfavorable odors and are recorded as sometimes occurring in vanilla. The judging committee considered the ethylene-treated beans the best of all groups, those treated by exposure to direct rays of the sun second best, by quick cold the third best, and by ultraviolet rays fourth best. The beans treated in the steam chamber were considered the worst, but it was felt that steaming for a shorter period of time might alter this conclusion.

The judging committee consisted of three members of the station staff who were not familiar with the identity of the treatments at the time of judging.

Methods are needed for evaluating quality of beans.

The foregoing experiments were handicapped by an absence of definite quantitative methods of evaluating the beans. Although the analyses for vanillin afforded a quantitative measure of some value, they proved to be of much less importance than had been expected. At the time the processing of these beans had been completed New York quotations for good Mexican beans were listed at from $4.50 to $5.50 per pound; synthetic vanillin crystals at the same time were quoted in New York at $2 to $2.50 per pound. It is evident that vanilla beans which contained approximately only 2 percent of vanillin sold for about twice the price per pound of pure vanillin crystals. Hence the conclusion seems logical that vanilla beans must contain other products several hundredfold more important to the consumer than vanillin, or they would not sell at such a superior price. Quantitative vanillin determinations therefore only have value if taken as an index of the formation of related compounds which give additional flavor and aroma to the beans.

The conclusion from the first year of processing studies has been that vanilla must for the most part be judged by organoleptic tests such as aroma and flavor in representative media. Vanilla, for the present at least, must be considered in the same category as tea and such other products which are also valued on the basis of organoleptic tests. However, two important definite quantitative factors in evaluation of vanilla at the present time would seem to be moisture content and freedom from molds.

The vanilla work reported here has been done by Charles F. Pennington, vanilla specialist, working in close cooperation with the plant physiologists, chemist, and other personnel of the station.

BAMBOO PROPAGATION AND UTILIZATION

Large, hard, borer-resistant bamboos have been propagated.

In previous annual reports of this experiment station the susceptibility of the commonly planted bamboo, *Bambusa vulgaris*, to boring insects has been mentioned. The introduction of new bamboo species has been recorded, as well as the findings that some of these new species in addition to being larger and stronger than *B. vulgaris* also had

considerable degree of resistance to boring insects. During the year under review the field work in this activity has been confined to the multiplication of these newly introduced species.

The Reconstruction Administration has greatly aided bamboo propagation.

The work of the Puerto Rico Reconstruction Administration in connection with these bamboo activities should be recorded. For 10 months during the fiscal year 25 men were available for the clearing and preparation of fields and for propagation work. Nurseries covering 7½ acres were developed. The species which were propagated in greatest numbers were *Bambusa tulda*, *Dendrocalamus strictus*, and *B. arundinacea*, more propagating material of these species having been available than of any other species.

At the close of the fiscal year 1,200 plants of these four species were available for distribution and permanent planting, with approximately 2,500 additional plants still in development in the nursery.

Industrial bamboos can be grown on otherwise nonproductive steep hillsides.

The bamboo nurseries have been maintained on station land which is level or nearly level so that in digging the plants for distribution the resulting loosening of the soil would not cause severe erosion. However, in permanent plantings, even on sloping hillsides, this factor does not have to be considered. Steep hillsides otherwise considered nonproductive have been planted to bamboos at the station; this practice can increase the areas of productive land in the island. Little cultivation is necessary after the permanent planting of most bamboos, the only attention needed being the cutting out of weeds and vines for the first year after planting. In other words there is no loosening of the soil in the production of bamboo in permanent plantings, and bamboo production is therefore well suited for steep hillsides, not only to avoid but also to check erosion.

New types of farm shelters have been constructed.

Because of the absence of industrial bamboos in any quantities, little has been possible in developing the mass production desirable for bamboo utilization. New types of furniture have been developed, some of which are suitable for export and others for the households of small farmers.

In the pastures of the experiment station some attractive and serviceable sheds with bamboo roofs have been constructed as shelters for domestic animals. Such a cattle shelter is shown in figure 15.

A view in the bamboo-utilization shop with some of the products which are being developed is shown in figure 16.

The projects for the propagation and utilization of bamboo have been carried on by Atherton Lee, director of the station, and Armando Arroyo, scientific aide.

Damage by the powder-post beetle can be minimized.

In the last annual report experiments were recorded showing that the tops of normal bamboo culms were less subject than the butts to attacks by the powder-post beetle, *Dinoderus minutus* (F.). It was also shown that topping bamboo culms tended to remove the nonsusceptibility.

Experiments also showed conclusively that exposure to fresh water materially lessened the beetle attacks in bamboo. Salt water seemed more effective in lessening the beetle attacks than fresh water. Some

FIGURE 15.—A rain shelter for cows, with a roof of bamboo, constructed at low cost.

FIGURE 16.—A view in the bamboo shop at the station showing articles of bamboo under construction, including desk lamps, tables, chairs, stools, a bookcase, benches, pitchers, and a bed.

proprietary creosote preparations were shown to be effective as treatments to prevent attacks by the powder-post beetle. During the year experiments of this nature were continued by Harold K.

Plank, associate entomologist. The following paragraphs summarize the most important results of his studies on these subjects.

Six species of bamboo were tested for susceptibility to the powder-post beetle.

Six species of bamboo as they became available during the year were tested in cage experiments to indicate their relative susceptibility to the attack of the bamboo powder-post beetle. These species were *Bambusa vulgaris*, *B. arundinacea*, *B. tulda*, *B. balcooa*, *Dendrocalamus strictus*, and *D. giganteus*.

In these susceptibility experiments freshly cut culms taken from different clumps were used. Following the technique developed last year, rings three-fourths of an inch in width instead of strips of split bamboo were used as test pieces. On account of the variation in susceptibility known to exist throughout the culm and the fact that the middle sections showed average susceptibility, eight rings were sawed from each of the two middle internodes of each culm tested. These rings were completely randomized in screened metal cages so that each species would be equally represented. Four hundred adult powder-post beetles were then liberated in each cage, and the test bamboo rings exposed to their attacks for 1 month, after which the number of beetle attacks on each ring was counted and recorded.

Two species of bamboo showed high resistance to the powder-post beetle.

In the first two experiments *Bambusa arundinacea*, *B. tulda*, and *Dendrocalamus strictus* of two age groups were each compared in separate cages with *B. vulgaris*. Table 10 gives a summary of the results secured with the younger and with the more mature culms.

TABLE 10.—*Comparison of susceptibility of uncured young and mature culms of four species of bamboo to the powder-post beetle*

[Each represents a summary of 2 separate experiments] [1]

Species	Approximate age of culms	Beetle attacks per ring, average	Susceptibility compared with *Bambusa vulgaris*
	YOUNG CULMS		
	Years	*Number*	*Percent*
Bambusa vulgaris	1. 5	6. 44–14. 31	100. 00
B. arundinacea	.9	0. 00	.00
B. tulda	.9	.06	0. 44–0. 97
Dendrocalamus strictus	.8	.03	.18– .79
	MATURE CULMS		
B. vulgaris	2. 5	3. 50–43. 44	100. 00
B. arundinacea	2. 0	.00	.00
B. tulda	2 0	.00	.00
Dendrocalamus strictus	1. 0	.00– .06	.00–1. 20

[1] Data recorded Nov. 30 to Dec. 29, 1936. Experiment by Plank.

From the summary given it was evident that culms of about 2 years of age of the two imported species of bamboo, *Bambusa arundinacea* and *B. tulda*, were highly resistant to powder-post beetle attack as compared with *B. vulgaris*. The number of beetle attacks in any one of the imported species was too small to indicate any significant differences in susceptibility among these species at the ages tested.

Old culms showed greater resistance to powder-post beetle than young culms.

The age at which the common bamboo, *Bambusa vulgaris*, is cut has long been thought to influence its resistance to the powder-post beetle. In order to accumulate as much data as possible on this point, the foregoing series of experiments was so arranged that common bamboo culms of two ages as widely separated as could be secured, namely, approximately 1.5 years and 2.5 years, were represented in each test.

Table 11, which follows, summarizes the attacks observed in the *Bambusa vulgaris* rings of different ages in the tests summarized in table 10.

TABLE 11.—*Powder-post beetle attacks observed in Bambusa vulgaris culms of 2 specified ages after exposure for 1 month in screened metal cages* [1]

Cage	Beetle attacks per 16 rings of each age		Susceptibility of "old" compared with "young"
	1.5 years	2.5 years	
	Number	*Number*	*Percent*
A	229	93	40.61
B	228	65	28.51
C	127	56	44.09
Total	584	214	36.64

[1] Data recorded Nov. 30 to Dec. 2, 1936. Experiment by Plank.

According to the data presented in table 11 it is evident that in these tests the older bamboo was not so susceptible to beetle attack as the younger, the total number of attacks on the culms 2½ years old being but 36.64 percent of the attacks found on the culms 1½ years old. This difference was highly significant according to statistical analyses by A. N. Watson, biometrician.

Young bamboo culms did not show the susceptibility gradient of old culms.

In order to observe differences in susceptibility between upper and lower internodes from the middle of the culms used in the foregoing tests, all rings were marked, and the respective beetle attacks recorded, according to the location in the culms from which the rings came—i. e., whether from an upper or from a lower internode.

The data thus secured are presented in table 12.

TABLE 12.—*Powder-post beetle attacks observed in test pieces from upper and lower middle internodes of Bambusa vulgaris culms of 2 specified ages exposed for 1 month in screened metal cages* [1]

Age of culms	Beetle attacks per 16 rings from each location		Susceptibility of "lower" compared with "upper"
	Upper internodes	Lower internodes	
	Number	*Number*	*Percent*
1.5 years	345	239	69.28
2.5 years	72	142	197.22
Total	417	381	91.37

[1] Borer channels counted Nov. 30 to Dec. 2, 1936. Experiment by Plank.

It is apparent from table 12 that the gradient of susceptibility at different heights in the bamboo culm changes with age. Previous experiments by Gibbons, Watson, and Lee have shown that the usual susceptibility of normal culms was less in the upper internodes than in the lower internodes. In the present experiment a rather interesting new conception was developed; in the case of the younger culm the upper parts were more susceptible than the lower parts, which was quite the reverse of the results by Gibbons et al. However, in the case of the more mature culm, the comparative susceptibility was reversed and the lower internodes were more susceptible than the upper internodes.

In view of the physiology of the bamboo culm, this new conception appears entirely logical. In the younger culms which have just finished their active growth, there has been no opportunity for the accumulation and storage of nutrients, while in the older culms storage of nutrients has taken place in the lower internodes. This last conclusion is drawn by analogy from the detailed understanding of the storage of sucrose in the related grass, sugarcane.

Dr. Watson found this interaction of age and location in bamboo to be highly significant.

In air-dried bamboo, beetle infestation was much reduced.

The culms remaining from the foregoing experiments were stored in a dry shed for about 2½ months from the latter part of October until December 19, 1936, and then used for another series of susceptibility tests. One culm of each age group had been taken from the same clump of each of the four species, *Bambusa vulgaris*, *B. arundinacea*, *B. tulda*, and *Dendrocalamus strictus*. A set of 16 rings, each the standard three-fourths inch in width, were sawed from the two inside internodes of each culm, 8 rings being taken from the internode adjacent to the last upper internode used in previous tests and 8 from the corresponding lower internode.

Table 13 shows the results secured with the dry young bamboo after 1 month's exposure to the attack of 400 powder-post beetles in a screened metal cage.

TABLE 13.—*Results of exposure to the powder-post beetle of test pieces of air-dried young culms of four species of bamboo* [1]

Symbol	Species	Approximate age of culm	Rings used	Beetle attacks per ring, average
		Years	*Number*	*Number*
1	*Bambusa vulgaris*	1.5	16	0.06
2	*B. arundinacea*	.9	16	.06
3	*B. tulda*	.9	16	.00
4	*Dendrocalamus strictus*	.8	16	2.31

[1] Test pieces exposed Dec. 19, 1936. Beetle infestations counted Jan. 19, 1937. Experiment by Plank.

Bambusa vulgaris and *B. arundinacea* each showed the same average number of beetle attacks per test piece, namely, 0.06; *B. tulda* was unattacked; and the *Dendrocalamus strictus* rings showed an average of 2.31 attacks each. Although some differences in susceptibility was shown between *Dendrocalamus strictus* and the other three species,

actually the number of beetle attacks was too small in any case to permit a comparison of any significance.

In table 14 are presented the data secured with the air-dried older culms of bamboo tested under the same conditions but in another cage.

TABLE 14.—*Results of exposure to the powder-post beetle of test pieces of air-dried old culms of four species of bamboo* [1]

Symbol	Species	Approximate age of culm	Rings used	Beetle attacks per ring, average
		Years	*Number*	*Number*
1	*Bambusa vulgaris*	2.5	16	0.69
2	*B. arundinacea*	2.0	16	.25
3	*B. tulda*	2.0	16	.00
4	*Dendrocalamus strictus*	1.0	16	.00

[1] Test pieces exposed Dec. 21, 1936. Beetle infestations counted Jan. 21, 1937. Experiment by Plank.

The comparatively slight susceptibility of old culms, especially when dried, of all species can be observed from the foregoing table.

This experiment was repeated using similar methods, and the identical results obtained amply support the conclusions from the first experiment.

An additional timber species of bamboo was found resistant to the powder-post beetle.

In a third experiment involving freshly cut culms, the above four species of bamboo and two additional species, namely, *Dendrocalamus giganteus* and *Bambusa balcooa*, were all tested together in the same cage for susceptibility to the powder-post beetle. Each species was represented by two culms from separate clumps. All 12 culms were in their second year of growth—i. e., they had begun to sprout in the spring or early summer of 1935—and were as near the same age as could be judged by experienced propagators.

Table 15 gives the number of beetle attacks found on the ring-test pieces of each species, listed according to the clumps from which the culms were taken. In the last column of this table the total number of attacks on each species is compared with that on *Bambusa vulgaris* to show the relative suceptibility.

TABLE 15.—*Susceptibility of two 2-year-old, freshly harvested culms of each of six species of bamboo to the attack of the powder-post beetle* [1]

Symbol	Species	Beetle attacks per 16 rings from—		Total beetle attacks per 32 rings	Average susceptibility compared with *Bambusa vulgaris*
		Clumps X	Clumps Y		
		Number	*Number*	*Number*	*Percent*
1	*Bambusa vulgaris*	53	32	85	100.00
2	*B. arundinacea*	2	2	4	4.71
3	*B. tulda*	8	2	10	11.76
4	*Dendrocalamus strictus*	65	66	131	154.12
5	*D. giganteus*	6	12	18	21.18
6	*B. balcooa*	19	194	213	250.59

[1] Culms harvested Feb. 26 to Mar. 9, 1937. Test pieces examined Apr. 13–20, 1937. Experiment by Plank.

Bambusa arundinacea was most resistant species in this test.

It is apparent from table 15 that *B. arundinacea*, *B. tulda*, and *D. giganteus* were resistant to the attack of the beetle, even though exposed to the insects without curing, the first sustaining in these experiments only 4.71 percent and the last 21.18 percent of the number of attacks found on *B. vulgaris*.

Table 16 shows the analysis of variance of all the data secured in the entire series of tests.

TABLE 16.—*Analysis of variance of data secured to show the susceptibility of six species of bamboo to the powder-post beetle in tests completed Apr. 20, 1937* [1]

Source of variance	Degrees of freedom	Variance	Significance [2]
1. Total	191	17.18	
2. Between classes	95	28.35	(**)
a. Species	5	217.36	(**)
b. Clumps	1	125.20	(**)
c. Positions	1	1.00	(–)
d. Cages	3	19.57	(*)
e. Interaction	85	16.73	(**)
1′. Species and clumps	5	169.58	(**)
2′. Species and positions	5	27.70	(**)
3′. Species and cages	15	6.59	(–)
4′. Clumps and positions	1	4.30	(–)
5′. Clumps and cages	3	12.13	(–)
6′. Positions and cages	3	.93	(–)
7′. Species, clumps, and positions	5	15.82	(*)
8′. Species, clumps, and cages	15	5.11	(–)
9′. Species, positions, and cages	15	.83	(–)
10′. Clumps, positions, and cages	3	7.47	(–)
11′. Species, clumps, positions, and cages	15	6.85	(–)
3. Within classes (error)	96	6.13	

[1] Statistical analysis by Plank and Watson.
[2] (–) Indicates no significance; (*) indicates significance; and (**) indicates high significance.

From the analysis presented in table 16 it was found that there were highly significant differences between the various species as regards susceptibility. On the basis of standard error, the difference in the number of beetle attacks on any two species would have to be 39 to indicate that this difference was significant and 52 to indicate high significance. The six species thus fell into two main groups: *Bambusa arundinacea*, *B. tulda*, and *Dendrocalamus giganteus*, among which there were no significant differences in susceptibility; and *B. vulgaris*, *D. strictus*, and *B. balcooa*, all of which not only differed in susceptibility in a highly significant way from the other three species, but also differed at least significantly from each other.

It is interesting to note that most of the beetle attacks found on the test pieces representing *Dendrocalamus strictus* and *Bambusa balcooa* were located in the softer portions of the wood near the center or inside, whereas in the other susceptible species the beetle attacks not only occurred in these regions but also extended in some cases well toward the outer wall of the bamboo.

Soaking whole bamboo culms in water gave protection against powder-post beetle.

Experiments by Gibbons, Watson, and Lee during 1936 showed about 60 percent protection from *Dinoderus minutus* in strips and rings of the common bamboo, *Bambusa vulgaris*, when soaked in fresh water for 6 weeks. With this work as a starting point, an extensive

series of experiments was conducted in which whole culms instead of pieces were tested and the time in water was increased to 8 weeks. These experiments were carried on using the same susceptible species, *B. vulgaris*.

Beginning on November 13, 1936, one normal culm of the current growing season was cut from each of five separate clumps on the station grounds. Immediately after cutting, the entire culms, minus the side branches and the tops of the culms down to about one-half inch in diameter, were placed in an irrigation reservoir of the station. The same procedure was followed at intervals of 2 weeks until three such lots of culms had been placed in the reservoir. There they were left until the first lot had been in the water for 8 weeks, the second lot 6 weeks, and the third 4 weeks. As no provision was made to hold the culms under water, most of their length was not completely submerged. At the end of the experiment all culms were removed from the water and a fourth lot of five similar culms was freshly cut, one from each of the original five clumps, to serve as checks on the treatments in the usual cage tests.

In table 17 are listed by treatments the number of beetle attacks found on the rings from the culms from the various clumps. These numbers are totaled for each treatment and the totals compared with that of the untreated check. This comparison, called "percent protection," is shown in the last column.

TABLE 17.—*Results of soaking Bambusa vulgaris culms in water for various lengths of time. The culms were cut from specified clumps Nov. 13, 1936, to Jan. 11, 1937, and the test pieces were exposed to beetle attack for 1 month, beginning Jan. 9–23, 1937* [1]

Treatment: time in water (weeks)	Beetle attacks per 16 rings in cages representing—					Total	Protection against beetle attack, average
	Clump A	Clump B	Clump C	Clump D	Clump E		
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*
None	535	310	253	217	43	1,358	0.00
4	348	35	179	223	9	794	41.53
6	110	83	13	241	6	453	66.64
8	5	0	7	44	21	77	94.33
Total	998	428	452	725	79	2,682	

[1] Test pieces examined Feb. 9–23, 1937. Experiment by Plank.

Table 18 shows the analysis of variance of all the data secured in this water-treatment experiment.

It is readily evident that soaking the culms in water for 8 weeks resulted in superior protection from the beetle, the number of beetle attacks observed being the lowest in test pieces so treated from all but clump E, and the average protection in the culms from all five clumps being 94.33 percent for this treatment. The treatment resulting in the next best protection was 6 weeks' soaking in water, which averaged 66.64 percent. The 4 weeks' treatment provided relatively poor protection, there occurring an average of nearly 10 beetle attacks per ring in the test pieces from the five culms thus treated, or only 41.53 percent less than the untreated check. The differences between treatments were found by statistical analysis to be highly significant.

TABLE 18.—*Analysis of variance of data secured in water-treatment experiments with Bambusa vulgaris, as protection against the bamboo powder-post beetle. Experiments completed in February 1937* [1]

Source of variance	Degrees of freedom	Variance	Significance [2]
1. Total	319	141.00	
2. Between classes	39	685.46	(**)
a. Between treatments	3	3,697.73	(**)
b. Between cages	4	1,862.25	(**)
c. Between positions	1	10.50	(–)
d. Interaction	31	263.88	(**)
1′. Cages and treatments	12	639.82	(**)
2′. Cages and positions	4	5.28	(–)
3′. Treatments and positions	3	60.30	(–)
4′. Cages, treatments, and positions	12	25.04	(–)
3. Within classes (error)	280	65.17	

[1] Statistical analysis by Plank and Watson.
[2] (–) Indicates no significance, odds less than 19 to 1; (*) indicates significance, odds between 19 to 1 and 99 to 1; (**) indicates high significance, odds 99 to 1 or greater.

Water soaking caused much root and sprout growth.

Despite the fact that all side branches and the top down to about one-half inch in diameter had been trimmed from all culms, sprouts up to 4 feet long and many roots of various lengths up to 8 inches grew from nearly all the internodes of the culms that had been in the water for longer than 4 weeks. In other words the culms continued to grow and exhaust plant nutrients already stored in the wood. The sprouts were the longest in the culms treated for 8 weeks and shortest in those treated 4 weeks. In general, root development, especially from the root zones about the basal four or five nodes, was proportional to the length of time in the water. Apparently soaking the whole culm is superior to soaking the split bamboo, for although in the latter case penetration by the water and diffusion of nutrients must be more rapid, the exhaustion of the nutrients from the wood is minimized because there is no germination and growth of buds.

It is of interest to note that the longer the culms were in the water the more water-soaked the wood appeared at the end of the treatment and the lighter in weight the rings were when they were examined 1 month later at the end of the test. About 2 tablespoonfuls of water were found in each of two middle internodes of one culm that had been soaked for 8 weeks. Little to none was found in similar locations in the other culms soaked for the same period, and none was found in those soaked for the shorter periods.

The data indicate that beetle attack is generally inversely proportional to the length of time in the water.

Dating of new bamboo culms was begun.

In order to maintain a supply of culms of known age for experimental and other purposes a system of labeling each sprout was started soon after the current season's new growth had started in many of the clumps on the station grounds. Each new shoot was first labeled temporarily with a paper tag bearing the date the shoot came out of the ground or, if this was not known, the height of the shoot above the ground at the time of labeling. This system provided a convenient method of keeping accurate age records on each culm until the culms had developed joints of sufficient length and hardness

to permit writing the desired information on the internode with india ink after the manner used by the Bureau of Plant Industry.

Scale insects attacked many species of bamboo in the station collection.

Though few insects have been observed to attack bamboo while growing in the field in Puerto Rico, three scales of greater or less importance have been noted on plantings on the station grounds and along the public roads. These scales were determined in the Bureau of Entomology and Plant Quarantine as *Asterolecanium bambusae* (Bdv.), *A. miliaris* (Bdv.), and *Chaetococcus bambusae* (Mask.).

Asterolecanium bambusae was found attacking many species of bamboo in the station collection. It was particularly abundant during the year under review on the twigs and culms of *Dendrocalamus strictus, D. latiflorus, Bambusa vulgaris,* and *B. tulda.* Some markings of the rind appeared to be caused by this species, and the culms had an undesirable appearance which would mar them for use in certain kinds of furniture.

Asterolecanium miliaris was the principal scale attacking B. vulgaris.

Asterolecanium miliaris, a small, flat, bluntly elongate scale, was found attacking the leaves, twigs, and culms of *Bambusa vulgaris, B. arundinacea,* and *B. ventricosa.* Infestations were particularly heavy on the leaves and culms of the common *B. vulgaris* growing along the public highways in the western and southwestern parts of the island. In some places the attack was so heavy as to cause the leaves to turn brown and fall prematurely. Here and even in light infestations the culms were blemished much in the same way as by bamboo scale, *A. bambusae.*

Another scale insect noted, but in considerably less abundance, was *Chaetococcus bambusae,* a large, purple, waxy, soft scale found beneath the partly dried bud sheaths clinging to the young culms of *Guadua angustifolia* and *Bambusa tulda.* This insect was never abundant at the station and has never appeared to cause any material damage to the growth and appearance of the culms.

No insect enemies were found attacking the bamboo scales.

Although many collections of *Asterolecanium bambusae* and *A. miliaris* were caged during the year for the emergence of parasites, none has been recovered to date.

Fungus disease was found attacking bamboo scale.

Late in the fall of 1936 a number of specimens of *Asterolecanium bambusae* attacked by a grayish white fungus were observed on the under side of some leaves of *Bambusa vulgaris* and *Dendrocalamus latiflorus* growing on the station grounds. These were submitted to Vera K. Charles, of the Bureau of Plant Industry, who after several examinations reported that the fungus was evidently a species of *Cladosporium.* Dr. Charles stated that there was also present a small quantity of mycelium resembling that of an *Entomophthora* but that no spores were present. Evidence of this disease was uncommon, and, judging from the prolificacy of the scale, the fungus exerted little economic control.

Bamboo scale predator brought from Jamaica.

While examining some bamboo in the Castleton Garden, Jamaica, British West Indies, Atherton Lee, director of the station, observed larvae and adults of a predatory coccinellid beetle feeding on the scale,

Asterolecanium bambusae, infesting this bamboo. A few predatory beetles and larvae were placed in a match box in order to have specimens for determination. On reaching the Dominican Republic 6 days later, Mr. Lee showed the material to the government entomologist there, Dr. Juan Gomez Menor O. The adults were still alive and it was suggested that an attempt be made to keep them alive for introduction into Puerto Rico. Dr. Gomez Menor O. identified the specimens as a species of *Chilocorus*. The material was placed in a larger box with fresh scale-insect material from the palm species, *Chrysalidocarpus lutescens*, and was brought to San Juan where it was turned over to W. A. McCubbin, plant quarantine inspector, on March 23.

On arrival in San Juan the material was examined by K. A. Bartlett, associate entomologist, who found two beetles living, seven dead, and four cast larval skins. The living beetles were removed and the box and all plant material destroyed. The two living adults were placed in a cage containing bamboo scale, *Asterolecanium bambusae*, and white papaya scale, *Aulacaspis pentagona* (Targ.). One adult died on March 27 and the other on March 28. Unfortunately they failed to reproduce. These beetles were later identified in the Bureau of Entomology and Plant Quarantine as *Chilocorus cacti* (L.).

Mr. Lee also collected in alcohol predatory beetle larvae of another coccinellid species feeding on the same bamboo scale at the Plant Introduction Gardens, Summit, Panama Canal Zone, and at Caracas, Venezuela. This material was determined as a *Scymnus* species by the Bureau of Entomology and Plant Quarantine.

VEGETABLE CROP INVESTIGATIONS

SWEETPOTATO BREEDING

Cooperative sweetpotato breeding work was continued with the Bureau of Plant Industry.

The cooperative sweetpotato breeding project with the Division of Fruit and Vegetable Crops and Diseases, of the Bureau of Plant Industry, United States Department of Agriculture, was continued during the past year. The breeding plats were planted in July, and blossoming began November 12. A heavy crop of blossoms was produced by plants of the Seedling 254 and Introduction 85986 varieties; a few blossoms were produced by Introduction 64377 and Mameyita plants, but very few opened on plants of the Porto Rico variety. The blossoming period reached a peak during the latter part of November and early December; the number of flowers decreased rapidly during the latter part of December, and only an occasional blossom could be found during January and the first part of February. Even though hundreds of flowers opened, only two fruits containing one seed each were found that had developed during this fall blossoming period.

A blossoming wave in spring followed autumn flowering.

A new wave of blossoming developed during the latter part of February and extended as late as the last week in March; a few blossoms could be found until the latter part of May.

In order to obtain as large a quantity of seed as possible, advantage was taken of this later blossoming and a series of open crosses was made that extended through March. In these so-called open crosses

the pollen transfers were made, but the flowers were not emasculated, nor were they protected in any way from the visits of insects afterwards. The results are shown in table 19.

TABLE 19.—*Results of open crossing of sweetpotato flowers from Feb. 28 to Mar. 25, 1937, at the experiment station, Mayaguez, P. R.*

Varieties crossed	Crosses effected	Fruits developed	Blossoms setting fruit	Seed produced
	Number	*Number*	*Percent*	*Number*
Seedling 254 ♀ × Porto Rico ♂	139	27	19.42	34
Introduction 64377 ♀ × Porto Rico ♂	166	21	12.65	24
Mameyita ♀ × Porto Rico ♂	80	9	11.25	9
Introduction 85986 ♀ × Porto Rico ♂	70	6	8.57	6
Big Stem Jersey ♀ × Porto Rico ♂	7	1	14.29	1
Introduction 47442 ♀ × Porto Rico ♂	8	0	.00	0
Yellow Jersey ♀ × Porto Rico ♂	2	0	.00	0
Porto Rico ♀ × Seedling 254 ♂	28	5	17.86	6
Introduction 64377 ♀ × Seedling 254 ♂	12	1	8.33	1
Mameyita ♀ × Seedling 254 ♂	1	0	.00	0
Big Stem Jersey ♀ × Seedling 254 ♂	3	0	.00	0
Porto Rico ♀ × Introduction 64377 ♂	32	14	43.75	17
Seedling 254 ♀ × Introduction 64377 ♂	5	2	40.00	2
Introduction 85986 ♀ × Introduction 64377 ♂	13	1	7.69	1
Introduction 22437 ♀ × Introduction 64377 ♂	1	1	100.00	1
Mameyita ♀ × Introduction 64377 ♂	6	0	.00	0
Big Stem Jersey ♀ × Introduction 64377 ♂	3	0	.00	0
Porto Rico ♀ × Mameyita ♂	39	2	5.13	2
Seedling 254 ♀ × Mameyita ♂	7	1	14.29	2
Big Stem Jersey ♀ × Mameyita ♂	2	0	.00	0
Porto Rico ♀ × Introduction 85936 ♂	38	4	10.53	8
Introduction 64377 ♀ × Introduction 85936 ♂	1	0	.00	0
Mameyita ♀ × Introduction 85936 ♂	10	2	20.00	2
Introduction 47442 ♀ × Introduction 85936 ♂	1	0	.00	0
Seedling 254 ♀ × Introduction 85936 ♂	2	0	.00	0
Big Stem Jersey ♀ × Introduction 85936 ♂	4	0	.00	0
Porto Rico ♀ × Introduction 47442 ♂	30	3	10.00	3
Introduction 85986 ♀ × Introduction 47442 ♂	1	0	.00	0
Introduction 85986 ♀ × Big Stem Jersey ♂	2	0	.00	0
Total	713	100	14.025	119

A 14-percent set of fruit was obtained.

From a total of 713 crosses, 100 fruits developed giving a set of 14.025 percent. Among the crosses listed in the table some appreciable differences can be seen in the percentages of blossoms that set fruit.

Among those pairs of varieties in which a reasonably large number of crosses was effected, of special interest was the cross Porto Rico ♀ × Introduction 64377 ♂ with a set of 43.75 percent as contrasted with Porto Rico ♀ × Mameyita ♂ with only 5.13 percent of the blossoms setting fruit.

The 119 seed resulting from all crosses, together with 52 additional seed that developed as a result of open pollination, were forwarded to the Division of Fruit and Vegetable Crops and Diseases at Beltsville, Md., for germination, propagation, and subsequent testing in the southern continental United States, Puerto Rico, and Hawaii.

Sweetpotato seed from open pollination occurred rarely in the spring and fall of 1936.

Experience with sweetpotato flowering during the spring and fall of 1936 suggested that in general seed rarely resulted from open pollination. However, the finding of 52 such seed during the spring of 1937 indicated that under certain conditions seed would develop following open pollination. With so many seed developing as a result

of open pollination when the open crosses were being made, the question arose as to the identity of the male parents of the seed developed by the crosses.

Few insects were observed among the sweetpotato flowers.

There were strong indications that there was little or no cross-pollination by insects, for only four individual insects that might have effected cross-pollination were observed working among the flowers during the entire period when the crossing was being done. It is probable therefore that most of the open pollinations resulting in seed development were self-pollinations and not crosses. There is no method of arriving at an accurate estimate of the proportion of the seed developing from the open crosses that was the result of selfing. With the male parentage in doubt, these seed are of no value for genetic studies, but their value for possible commercial production is not necessarily impaired.

Previous observations on flowering of sweetpotatoes were confirmed.

Of the observations on the flowering of sweetpotatoes during the spring of 1936, included in the last annual report of the station, the following were substantiated by further observations during the past year: Plants of different varieties planted at the same time varied widely in their flowering responses; even plants within the same variety differed widely in this respect. In no variety did 100 percent of the plants blossom; some that formed blossom buds failed to produce any blossoms. Not all blossom buds formed on the same branch developed into blossoms, for many abscised during various stages of development. All branches of the same plant did not give the same flowering response. The blossoming behavior of the plants could not be associated with the size of plant, either among varieties or among plants of the same variety.

All varieties grown have produced flowers in Puerto Rico except Vineland Bush.

Under conditions in Puerto Rico, the Vineland Bush variety has not yet produced blossoms, the Introduction 22437 variety has produced only two flowers, and flower production has been very light for Yellow Jersey, Big Stem Jersey, and Introduction 47442. Somewhat better flower production has resulted with Mameyita and Porto Rico, and Introductions 85986 and 64377 have blossomed freely.

Two distinct types of sweetpotato fruits were produced.

Two distinct types of sweetpotato fruits were produced from the 16 crosses from which seed were obtained during the past year. The fruits of those of the Big Stem Jersey, Seedling 254, and Introductions 85986 and 64377 varieties were glabrous; those of Porto Rico and Mameyita were covered with numerous long hairs. Fruits typical of these two types are shown in figure 17.

Physiological condition of the plants appeared to be a factor in flowering and fruiting.

Previous work at this experiment station and elsewhere has shown that day length is a factor in the blossoming of sweetpotatoes. From the results obtained during the present breeding work it appears that the physiological age or condition of the plants, as well as length of day, has also been a factor in sweetpotato flowering and especially in the setting of fruit and subsequent seed development.

The sweetpotato plants that flowered during the spring of 1936 were only 8 to 10 weeks old; the day length was gradually increasing and approaching 12 hours; and few seed were produced. The plants blossoming in the fall of 1936 were about 4 months old; the day length was approximately 11.3 hours and slowly decreasing; practically no seed were produced. The planting that blossomed in the spring of 1937 was 7 to 8 months old; the day length increased from approximately 11.7 hours to 12.1 hours during the blossoming period; and more than 171 seed were produced, of which 119 were from open crosses while the balance were from naturally pollinated flowers. At the time of this last flowering and fruit production the plants were

FIGURE 17.—Sweetpotato fruits typical of the two distinct types produced by varieties in the breeding plat of the experiment station.

drawing on the reserve carbohydrates that had been stored in the roots during the fall months.

At the close of the breeding season flower production in some varieties and fruit setting and seed development in most varieties were still considered far from satisfactory.

CALABAZA BREEDING

Inbreeding of calabazas was started to isolate and fix uniform high-quality strains.

In the 1936 annual report of the station it was shown that 92 different types of calabazas had been collected, photographed, and described and the seed saved for plant-breeding and genetic studies.

One hundred and twenty-two additional types were collected during the past year for the same purposes.

Canned calabazas have excellent flavor and have been well received by continental bakers for pie making. However, the baking trade demands a more uniform product than can be supplied from Puerto Rico at present due to the extreme variability that exists among calabazas here. In an effort to develop calabazas that will meet this demand as well as to develop uniformly high-yielding types which have superior table quality, seed of the 92 types which were collected during 1936 were planted for inbreeding. Ninety-three fruits were obtained as a result of the selfing of approximately 1,000 pistillate flowers. Seed of these fruits have been planted to determine resulting fruit uniformity, or for further inbreeding if the desired uniformity is not secured as a result of the one generation of inbreeding.

SWEET CORN BREEDING AND REGIONAL ADAPTATION STUDIES

USDA–34 sweet corn is not yet uniform for plant and ear characters.

In the annual report for 1935 an account was given of the development at the station of two sweet corn varieties adapted to Puerto Rico, namely, USDA–32 and USDA–34. The two varieties were so similar that USDA–32 has since been discarded. When this sweet corn was introduced, considerable variability existed in color of stalks, husks, and cobs, and to a minor extent in color of kernels as well as in size and shape of kernels, extent of pseudostarchiness, and thickness of pericarp.

During the past year inbreeding was started in an effort to eliminate some of this lack of uniformity by isolating and fixing more uniform and more desirable strains. To date approximately 2,000 plants have been selfed, and from the resulting ears 90 have been selected for further inbreeding.

Plantings of USDA–34 sweet corn have been extended.

USDA–34 sweet corn has continued to gain favor, and plantings have been extended in the island. The experiment station distributed more than 750 pounds of seed during the year, and the demand for seed exceeded the supply.

This variety of sweet corn was tested in Hawaii and in the southern continental United States by various experiment stations and private growers during the past year, and favorable comments on the variety have been received.

USDA–34 sweet corn has been introduced into Florida, Louisiana, and Hawaii.

USDA–34 sweet corn was introduced into Hawaii in 1935 through the Hawaii Agricultural Experiment Station, and C. P. Wilsie, agronomist of that station, reported that promising results have been obtained with the corn there. It behaved similarly to the Guam corn in that it had large stalks, tight husks, and little earworm damage, but the eating quality was reported much superior to that of the Guam corn.

A. Daane, agronomist in charge of the Florida Everglades Experiment Station at Belle Glade, Fla., reported that in spite of adverse weather conditions sufficient evidence was obtained to consider USDA–34 sweet corn equal to if not better than other sweet corn that

had been tried there. He reported also that the corn was able to withstand insect attacks much better than any of the other sweet corn varieties and that a larger percentage of marketable ears was obtained.

Julian C. Miller, head of research in horticulture at the Louisiana Experiment Station, stated that USDA–34 sweet corn grew vigorously but was later than Stowell's Evergreen, maturing in about the same number of days as Texas Sure-Crop-Sugar and Honey-Dew.

E. V. Abbott reported that USDA–34 sweet corn grew vigorously at Houma, La., but matured late. Every stalk produced two good ears, and the yield was estimated at one and one-half to two times that of Golden Bantam.

In North Carolina and Ohio USDA–34 matured later than other varieties.

Robert Schmidt, associate horticulturist of the North Carolina Experiment Station at State College Station, Raleigh, stated that USDA–34 sweet corn made a tremendous growth, the stalks becoming 9 feet tall before tasseling and that it matured, reached roasting-ear stage, in 83 days, approximately 3 weeks later than Golden Bantam, Howling Mob, Golden Cross Bantam, and Whipcross. Mr. Schmidt objected to the lateness of maturity but suggested that its tremendous growth might make it valuable as a combination roasting-ear and fodder corn.

A. E. Waller, associate professor of botany of Ohio State University, reported that USDA–34 sweet corn made vigorous growth in spite of an intense drought, but it was late in maturing.

PHYSIOLOGICAL, STORAGE, AND PROPAGATION STUDIES WITH YAMS

Ñames do not keep well in storage.

Ñames, or true yams, *Dioscorea* spp., are a popular food crop in Puerto Rico. They are used commonly as a substitute for potatoes, especially among the less well-to-do classes, and continentals often prefer them to potatoes. One of the chief difficulties with yams is that the tubers do not keep well in storage, especially if they have been injured during harvest. When a crop matures at the beginning of or during a dry season, it is a common practice to allow the tubers to remain in the soil until such time as they are to be sold or used for home consumption. While this crop can be grown, and is grown to a certain extent, throughout the entire year in many sections of the island, most of the plantings are made in the spring and the crop is harvested during the late fall or early winter. Yields are reported as being much greater for the spring-planted crop than for those planted at other seasons of the year.

Methods of increasing storage life of yams have been studied.

During the past year several preliminary experiments were conducted in order to determine something of the storage behavior of Guinea yam tubers and to ascertain, if possible, methods of increasing their storage life.

With these two objectives in mind, 50 recently harvested, uninjured, uniformly cylindrical-shaped Guinea tubers were selected, carefully weighed and placed in open boxes in a refrigerated room where the temperature was maintained at approximately 34° F. Ten days later the refrigeration was discontinued.

Yams cannot withstand a storage temperature as low as 34° F.

An examination of the tubers 3 days later, 13 days after storage, disclosed that they were already in a well advanced stage of physiological break-down. The skin of the tubers, which was tight at the beginning of storage, had become separated from the flesh, was loose, and could be easily torn off with the fingers. The tissue beneath the skin was discolored and slimy, while the tubers as a whole were somewhat rubbery or flexible instead of being turgid as when they were stored. All were a complete loss. Within a week after being removed from cold storage the tubers were a watery sodden mass as the combined result of the physiological break-down in storage and subsequent fungus infections.

The results of this test indicated that yams, at least Guinea yams, cannot withstand a storage temperature as low as 34° F.

Potato yams have been kept at natural temperatures for 9 months.

Contrary to popular opinion, Potato yams which had not been injured in handling incident to harvesting and storage kept well for 9 months at natural temperatures and humidities. The tubers were shriveled at the end of this time, but were still edible, and when planted, almost all tubers produced vigorous plants.

The possibility of being able to store yams for several months under natural conditions suggested the desirability of knowing something of the weight losses of yams during such storage. Accordingly, from a large lot of Guinea yams which had been harvested for approximately 2 weeks, 150 sound, uniformly cylindrical tubers were selected. Twenty-five of the tubers were small, 100 were medium-sized, and 25 were large. The weight of each tuber was carefully determined and recorded. The 25 large tubers, 25 of the medium-sized tubers, and the 25 small tubers were loosely stacked in open boxes. Fifty more of the medium-sized tubers were given the prestorage treatment of a dip in 4–4–50 bordeaux mixture. Twenty-five of the treated tubers were placed in open boxes with the untreated tubers.

It has been reported that in Barbados excellent results have been obtained by storing yams immediately following harvest in a dry place between layers of dry wood ashes. To give this method a trial, 25 of the tubers treated with bordeaux and the remaining 25 of the untreated medium-sized tubers were packed in open boxes between layers of dry ashes. All boxes were stored in a poorly ventilated damp room, the only storage place available at that time.

Only 31 percent of the tubers appeared to be sound after 87 days in storage.

All tubers except those stored in ashes were weighed individually after 12, 34, and 47 days of storage and at 10-day intervals thereafter until the test was terminated on the eighty-seventh day. By this time a large proportion of the tubers showed fungus infections and decay. Neither the bordeaux prestorage dip nor storage in ashes effectively reduced the proportion of infected tubers. Of the 100 tubers stored in the open boxes, 31 percent were sound at the end of the test, approximately 100 days after they had been harvested, and 15 percent were so badly decayed that they were a total loss. Thirty percent of the 50 tubers stored in ashes were sound at the end of the storage period. However, this was not considered a fair test, because the ashes in part of one box became wet during the storage period.

Although this experiment was disappointing from the commercial point of view, it showed the relatively short storage life of the yam and emphasized the desirability of determining practical means of lengthening this storage life.

Sound Guinea yam tubers lost 7.76 percent of their weight in 87 days' storage.

The weight records of the yams which remained sound at the end of the test were grouped together and the percent weight losses for the group were averaged. Similarly the weight records of the tubers which became slightly infected were grouped as were also those that were badly decayed; the percent weight losses of each group were then averaged. In table 20 is shown the mean percent weight loss per tuber for each group together with the corresponding standard error of the mean at the different weighing dates during the storage period. Border-line tubers were not included in the averages. The averages are shown graphically in figure 18. It can be seen both in the table

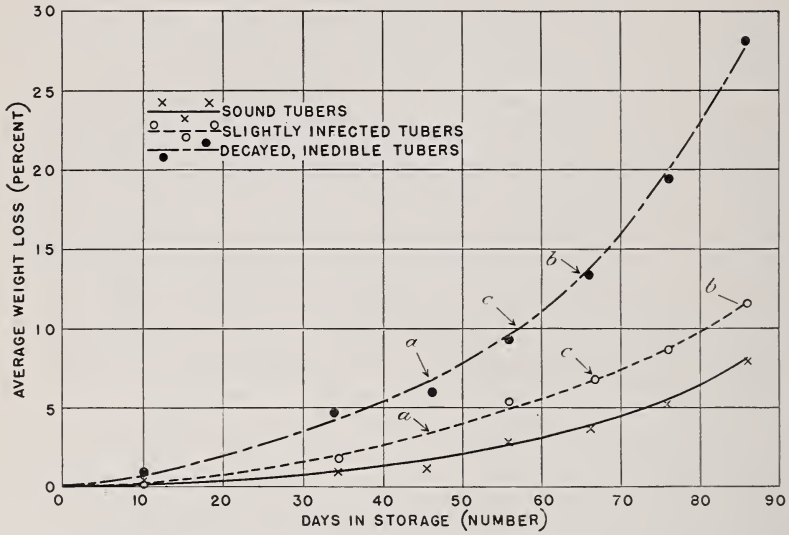

FIGURE 18.—Average percent weight losses of Guinea yams, grouped according to degree of decay, at different periods during storage: *a*, Date first infected tubers observed; *b*, date all tubers in these groups showed infection; *c*, mean number of days after storage for infection all tubers in these groups.

and from the chart that differences in average weight losses among the three groups of tubers became apparent before the end of the first 34 days of storage and that these differences became greater as the test progressed. For the sound tubers the average weight loss per tuber was negligible for the first 34 days, but increased thereafter until at the end of the 87-day period the average loss was 7.76 percent of the weight of the tubers at the beginning of the test.

TABLE 20.—*Average loss in weight of Guinea yams grouped according to degree of decay at different periods during storage*

Condition of tubers	Tubers	Average weight loss of tubers during progress of storage			
		12 days	34 days	47 days	57 days
	Number	*Percent*	*Percent*	*Percent*	*Percent*
Sound	31	0.44±0.080	[1] 0.97±0.226	1.83±0.204	2.75±0.224
Slightly infected	14	.29± .091	1.94± .247	3.97± .394	5.39± .426
Decayed, inedible	9	.82± .388	[2] 4.95±1.720	5.87±1.542	9.20±1.793

Condition of tubers	Tubers	Average weight loss of tubers during progress of storage		
		67 days	77 days	87 days
	Number	*Percent*	*Percent*	*Percent*
Sound	31	3.66±0.292	5.45±0.472	7.76±0.527
Slightly infected	14	6.87± .538	8.58± .649	11.01± .784
Decayed, inedible	9	13.61±2.007	19.35±2.159	28.00±2.819

[1] Average based on 15 tubers.
[2] Average based on 5 tubers.

Differences in weight between sound and infected tubers occurred before infections were detected.

Of particular interest is the fact that in both the slightly infected group and the inedible group, mean weight-loss increases occurred fully 20 days before the first tuber in either group was detected as being infected. This indicated that the infections were present and causing this increased weight loss for about 3 weeks before they were detected, or that there was some physiological change or changes in the tubers themselves which resulted in an increased weight loss and at the same time made the tubers more susceptible to fungus infections.

Careful handling of Guinea yams during harvesting and storing prevented tuber losses.

The need for careful handling of Potato yam tubers during harvesting and storage operations was pointed out in the annual report of the station for 1936. With Guinea yams the need for careful handling during harvest and handling incident to storage is even more imperative. Each plant usually produced only one tuber, the tubers from well-grown plants often weighing as much as 10 to 20 pounds each. If the skin of these tubers was broken and the fleshy part of the tubers exposed during harvest and storage operations, many of such tubers became infected and soon became a total loss for human consumption. In addition to the partial or complete loss of the infected tubers themselves, infected, rapidly decaying tubers stored among sound tubers were a potential source of infection for the sound tubers.

Island farmers treat harvest wounds of yam tubers with wood ashes.

Some of the country people of Puerto Rico reputedly cover harvest wounds of yam tubers with wood ashes in attempts to prevent infection and thereby prolong the storage life of the tubers. Two experiments were conducted during the winter in order to determine the

soundness of this practice and to compare the relative effectiveness of wood ashes with a number of other economical and practical physical and chemical agents in minimizing infection of cut surfaces of Guinea yam tubers. The treatments consisted of wood ashes, powdered charcoal, flowers of sulphur, powdered talc, hydrated lime, bordeaux mixture, and no treatment as a check. All materials were applied dry except the bordeaux, a 4–4–50 mixture of which was used as a dip. Twelve replicated groups of five tubers each were used for each treatment. Uniformly cylindrical-shaped tubers of small to medium size were selected. A clean cut with a sharp knife was made from 2 to 6 inches from the apical end and at right angles to the long axis of each tuber, and the cut surfaces were treated and the tubers stored immediately. The tubers for each treatment replication were chosen strictly at random, and the tuber groups for the different treatments were arranged at random within each replication group.

Hydrated lime, wood ashes, and bordeaux mixture delayed fungus infection.

The treatments were given a severe test, for the experiment was conducted during the rainy season and the treated tubers were stored on shelves in a poorly ventilated room where the floor was wet most of the time. Storage conditions were so conducive to fungus growth that after 2 weeks 100 percent of the sulphur, powdered charcoal, talc, and check tubers showed evidence of infection at the treated surfaces. The bordeaux treatment showed 80 percent infection, and the ashes and lime treatments 32 percent each. Two weeks later all bordeaux-treated tubers were infected, as were also 98 percent of those treated with lime and 96 percent of those treated with ashes.

The delayed infection which resulted from the use of ashes and lime, and to a minor extent the bordeaux mixture, indicated that there were possibilities that these treatments would prove commercially effective in reducing infection provided the tubers were stored under more favorable conditions.

Storage was tested under different conditions of ventilation.

In a second experiment the same seven treatments were given to tubers stored under varying conditions. The storage conditions were as follows:

(1) Forty-eight hours in an open, airy, dry place where treated surfaces were exposed to the sun from 2 p. m. to 6 p. m. daily, and subsequent storage in shade in an open, airy, dry place.

(2) Forty-eight hours in an open, airy, dry place where treated surfaces were exposed to the sun from 2 p. m. to 6 p. m. daily, and subsequent storage in a poorly ventilated room with relatively high humidity.

(3) Storage, immediately following treatment, in a poorly ventilated room with high humidity.

There were five replications of three tubers each for each of the seven treatments under each of the three storage conditions, making a total of 15 tubers per treatment under each storage condition, or a total of 45 tubers per treatment. Treatments were made January 30, 1937, and infection readings were taken at 10-day intervals thereafter for a period of 50 days. Results for the different methods of storage irrespective of treatments are shown by inspection intervals in table 21.

TABLE 21.—*Percent of cut Guinea yam tubers showing infection after specified lengths of time under different storage conditions*

Method of storage	Tubers stored	Tubers infected at storage intervals				
		10 days	20 days	30 days	40 days	50 days
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
(1) Open, airy, dry storage	105	3.8	9.5	15.2	17.0	44.8
(2) 48 hours open, airy, dry storage followed by poorly ventilated damp storage	105	6.7	14.3	19.0	24.8	50.5
(3) Poorly ventilated damp storage	105	53.3	61.0	66.7	69.5	81.9

It can be seen that under the conditions of this experiment there was little difference in infection at any time among the cut yams in the first two methods of storage.

Dry, well-ventilated storage reduced decay.

When the cut tubers were placed directly in the damp room the percentage of tubers infected was greater after only 10 days' storage than were the percentages for either of the other two treatments after 50 days' storage; at the end of the 50-day period the proportion of infected tubers in this group had increased to 81.9 percent.

Results for the treatments to prevent infection under all these storage conditions combined and for different storage intervals are shown in table 22.

TABLE 22.—*Different prestorage treatments of cut Guinea yam tubers and percentage of infection after different lengths of time in storage*

Treatment	Tubers	Tubers infected at storage intervals				
		10 days	20 days	30 days	40 days	50 days
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Wood ashes	45	0.0	0.0	0.0	0.0	19.9
Bordeaux mixture	45	4.4	13.3	17.7	22.2	37.8
Hydrated lime	45	4.4	11.1	22.2	26.7	48.8
Powdered charcoal	45	35.5	35.5	42.2	44.4	71.1
Powdered talc	45	37.7	53.3	55.5	62.2	77.7
Sulphur	45	35.5	48.9	55.5	57.8	91.1
Check	45	31.1	35.5	42.2	46.6	66.6

Wood ashes gave better results than bordeaux mixture.

The most striking result, as shown in table 22, was the marked superiority of wood ashes over the other treatments and the check. At the end of 50 days less than 20 percent of the tubers treated with ashes showed infections. The next best treatment was the bordeaux, which prevented all but 37.8 percent infection, closely followed by hydrated lime with 48.8 percent infection. Powdered charcoal gave final results that were inferior to the check, but the difference between them was not great. The sulphur and talc treatments, on the other hand, were definitely inferior to the check.

Table 22 shows a marked increase in infection between the 40- and 50-day periods. This is due largely to the fact that the final infection inspections, at the end of 50 days, were made approximately one-fourth of an inch back of the treated surfaces instead of being made

at the surface. As a result of this careful inspection some tubers which showed no infection at the treated surfaces were found to be infected just beneath the layer of dried tuber tissue which was associated with the cutting and the treatments which followed.

Ash-treated tubers showed little decay even under worst storage conditions.

In considering the final results of the treatments by storage conditions as presented in table 23, it can be seen that while wood ashes were superior to all other treatments under all storage conditions, the differences between the other treatments and the ashes were far greater with the tubers that were stored in the poorly ventilated damp room. With only 20 percent infection in damp storage, ashes were more than three times as efficient in tuber preservation as the next best treatment. Furthermore, the ashes gave only 6.7 percent more infection in damp storage than in dry storage. At the end of 50 days' damp storage all of the check tubers and all tubers treated with charcoal, talc, and sulphur had become infected.

TABLE 23.—*Percent of cut Guinea yam tubers with different treatments, showing infection at end of 50 days under different storage conditions*

Treatment	Tubers in each storage	Tubers infected under indicated storage conditions		
		Airy, dry storage	Airy, dry storage for 48 hours followed by poorly ventilated damp storage	Poorly ventilated damp storage
	Number	*Percent*	*Percent*	*Percent*
Wood ashes	15	13.3	13.3	20.0
Bordeaux mixture	15	20.0	20.0	73.3
Hydrated lime	15	46.7	33.3	66.7
Powdered charcoal	15	53.3	60.0	100.0
Powdered talc	15	66.7	66.7	100.0
Sulphur	15	86.7	86.7	100.0
Check	15	26.7	73.3	100.0

Decay was lessened in continuous dry storage.

Among the treated tubres there were no great differences between the proportions infected for each treatment under the other two storage conditions except for the lime-treated tubers; for this treatment the difference was in favor of the damp storage following a short period of dry storage. No explanation can be given for this unusual response by the tubers treated with hydrated lime.

Where no treatments were applied, the continuous dry storage was by far more efficient in preventing infection than a short period in dry storage followed by damp storage. The proportion of the untreated tubers infected in dry storage was only 26.7 percent, while in damp storage following 48 hours in dry storage it was 73 percent.

Wood ashes was the only satisfactory treatment in damp storage.

The results of these two tests indicate that the use of wood ashes to minimize decay resulting from harvest injuries to Guinea yam tubers is a sound practice. Ashes were consistently the best mate-

rial used for all storage conditions, and in unfavorable, damp storage, the only material to give reasonably effective control of infection.

However, the high proportion of infections, even under the best of the storage conditions, indicates: (1) That injuries to tubers during harvest and storing operations should be kept at a minimum; (2) if injuries do occur, the injured portions of the tubers should be treated immediately with wood ashes; and (3) the tubers should be stored in a dry, well-ventilated place until used or sold, or if such a place is unavailable for storage, they should be kept in an airy, dry place for at least 2 days and preferably longer, with the tubers so arranged that the treated injured tissues will have an opportunity to heal over before the tubers are placed in final storage.

Wood ashes reduced cracking of treated surfaces of tubers.

Three other factors were found to be of importance in connection with Guinea yam storage, namely, sprout development following the end of the rest period, cracking, and mouse and rat injury. The quantity of tubers consumed by rodents was small, but the corky epidermal covering was gnawed away in places, and the succulent storage tissue was thereby exposed to fungus infection and early decay. The cracking of the cut surfaces of the tubers in continuous dry storage was especially bad with the untreated tubers and those given the bordeaux, the lime, and the sulphur treatments. Very little cracking resulted when the tubers were treated with wood ashes. Cracking was not an important factor under damp storage conditions. Sprouting caused injury from loss of stored nutrients.

Size of seed pieces influenced yields of yams.

Kinman makes the following statement with regard to the propagation of yams: [2]

> To secure heavy yields, seed pieces of good size should be planted. One to 2-ounce pieces are often planted * * * but pieces weighing from 4 to 5 ounces should be used. Tests made at the station with different-sized seed pieces of common varieties and with entire tubers of some of the small-rooted varieties showed that a good gain in yield was made by using large rather than small seed pieces.

In a preliminary experiment conducted on Las Mesas during the past year with Morado yams, evidence was obtained which indicated that increased yields might be expected with this variety from the use of seed tubers even larger than 4 to 5 ounces.

There were 15 single-hill replications of each of six different sizes of tubers, with the average weight per tuber among the size groups ranging from 0.67 ounce to 44.27 ounces. In planting, the tubers were arranged within each replication in the order of their size. The rows were 3.5 feet apart and the hills 2 feet apart in the row.

Yields per hill averaged from 1.13 pounds with the smallest size seed tubers to 10.62 pounds with the largest size. Increasing the average size of tubers planted, from 0.67 ounce to 2.13 ounces, resulted in average yield increase of 26.2 pounds for each additional pound of tubers used in planting. The efficiency of the larger size of seed tubers in giving increases in yields decreased as the seed tuber size increased. Nevertheless, increasing the size of tubers planted, from an average of 25.6 ounces to an average of 44.27 ounces, resulted in a

[2] KINMAN, C. R. YAM CULTURE IN PORTO RICO. Porto Rico Agr. Expt. Sta. Bull. 27, 22 pp., illus. 1921. See p. 6.

mean increased yield of 3.1 pounds for each additional pound of tubers planted.

This experiment was a small one, and the results are considered as preliminary, merely indicative that further studies along this same line might be expected to yield promising results.

Replicated size-of-seed-tuber tests were made with Potato yam varieties.

A similar size-of-seed-tuber study was made with Tongo yams and similar but more extensive size-of-tuber tests were made with the Potato 592, Potato 652, and Potato 342 varieties. All four of these varieties produce numerous small tubers as contrasted to the Morado variety which produces few tubers, and often only one, per hill.

The tubers were harvested in February 1937, but because of pressure of other activities weighings were not obtained until after the tubers

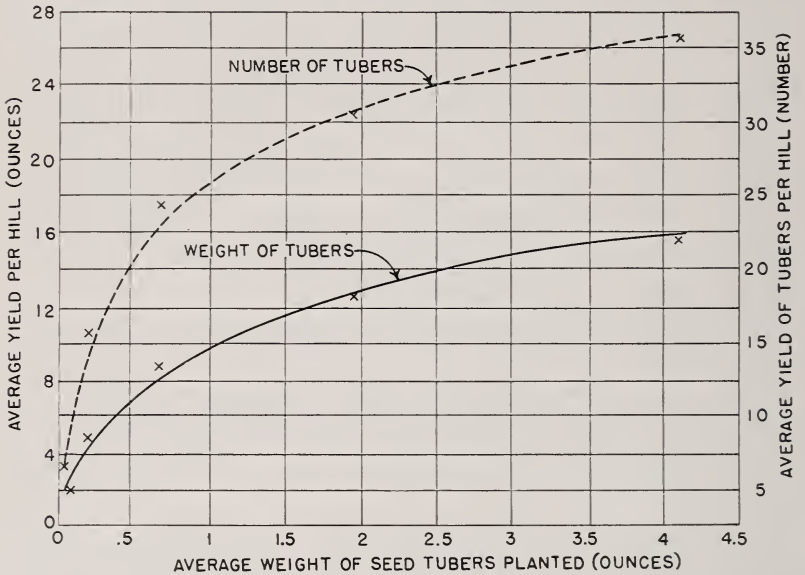

FIGURE 19.—Average yield per hill of Potato 592 yams in relation to size of seed tubers planted.

had remained in common storage for approximately 8 months. Obviously, then, the yields themselves, as recorded, are limited in value. However, the proportionate differences in yield for the different size seed-piece groups are of considerable interest, and there is reason to believe that the relationships which were found to exist between these groups at the time the records were taken were approximately the same as they were at the time the tubers were harvested. The increase in yield as measured by both average weight and average number of tubers produced per hill for increasing size of tubers planted is shown graphically for Potato 592 in figure 19.

Increases were obtained in both number and weight of tubers per hill.

It can be seen from the shape of the curves in figure 19 that the yield of tubers per hill, both in number and weight, increased sharply as the size of seed tubers increased, the smallest yields occurring when the smallest seed tubers were planted. The rate of increase was small

after the average weight of seed tubers reached 2 ounces, and it is probable that appreciable increases in yield would not have resulted from the use of seed tubers larger than 4.25 to 4.50 ounces.

It is of interest to note in figure 19 that increases in weight resulting from larger seed tubers were closely paralleled by proportional increases in numbers of tubers. One point that was not brought out by the chart, and which is of importance, is that the use of very small seed tubers resulted in a poor stand of plants. With seed tubers averaging 0.0533 ounce for Potato 652, a stand of only 52 percent was obtained; and with 0.064-ounce Potato 592 seed tubers the stand was only 41 percent.

In similar size-of-seed-tuber studies with Potato 342 and Tongo varieties, for which yield records were not obtained, a stand of 60 percent was obtained from Potato 342 seed tubers averaging 0.064 ounce and a 58-percent stand with small Tongo seed tubers. A small reduction in stand occurred with seed tubers of all varieties weighing an average of approximately one-fourth of an ounce, but with larger seed tubers there was only an occasional missing hill, and such missing hills were not correlated with the size of tubers planted.

In the test with Potato 592 there were 10 replications of 5 hills each for 5 different seed-tuber sizes; and with Potato 652 there were 12 replications of 5 hills each for 6 tuber sizes.

In interpreting the results of these seed-tuber studies with small-tuber-type yams, it should be kept in mind that the seed tubers had been kept in common storage for approximately 5 months before being planted. It is possible that different results might have been obtained had the tubers not remained in storage so long.

A positive correlation was found between weight of tops and yield of tubers.

A high degree of correlation was found to exist between air-dry weight of tops and tuber yields with Morado yams grown on Las Mesas. The calculations were based on the yield values for tubers and tops from 87 of the hills used in the size-of-seed-tuber study and similar data for 20 additional hills grown adjacent to the seed-tuber test hills, making a total of 107 pairs of values.

A positive coefficient of linear correlation of 0.8262 was found to exist between tuber yields and air-dry weight of tops, giving a degree of determination of 68.26 percent. Stated in another way, variations in air-dry weight of tops were accompanied by proportional variations in yields of tubers in 68.26 percent of the cases. This relationship between dry weight of tops and yield of tubers is shown in the form of a dot diagram in figure 20.

Seed tubers from low-yielding hills gave results as good as those from high-yielding hills.

True seed production in cultivated yams is rare. Propagation is accomplished vegetatively by means of tubers or portions of tubers. It is well established among plant breeders that variations which can be propagated cannot normally be expected to occur in crops that are propagated vegetatively, such as yams, unless bud mutations occur or unless the stocks become mixed mechanically. With this fact in mind, tests were made during the past year to determine if certain of the most striking variations observed in yam variety stocks could be propagated.

With the crop of small-tubered-type yams harvested in February 1936, wide variations in yield per hill were obtained within varieties. A series of tests was made with the Potato 592, Potato 652, Potato 342, and Tongo varieties to determine whether some of these extreme variations in yield were the result of environmental conditions or whether they could be propagated. Medium-size tubers were selected from hills yielding more than 1,200 grams and from hills yielding less than 300 grams for all varieties except Tongo where the minimum limit for the high-yielding hills was 1,800 grams. The tubers from high-yielding and low-yielding hills for each variety were planted in

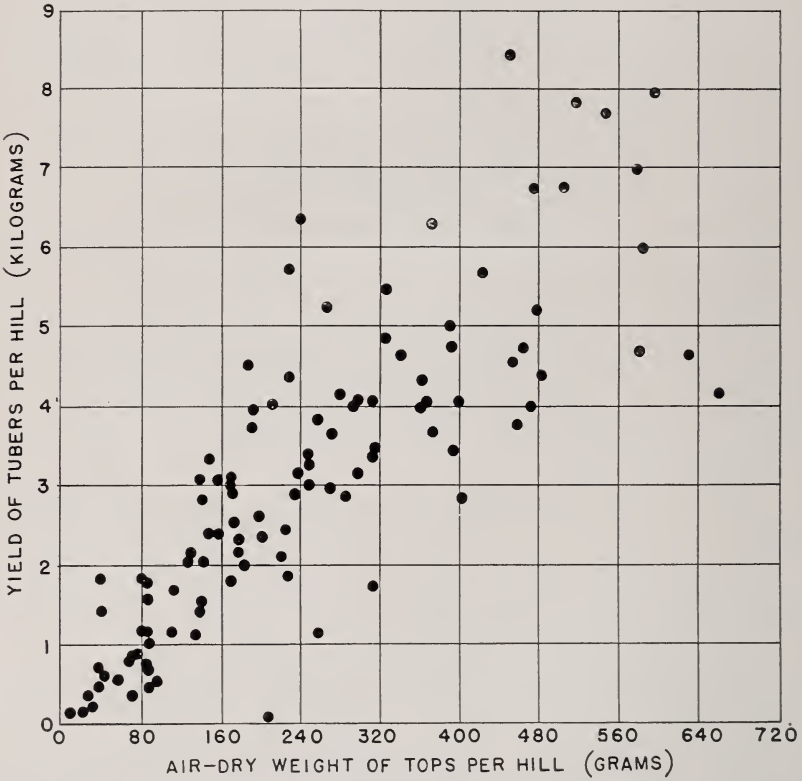

FIGURE 20.—Tuber yields as related to air-dry weights of tops of Morado yams.

the same rows in alternate hills, each variety occupying a separate section of the field. The number of tubers used in these tests varied from 34 with Potato 652 to 160 with Potato 592.

It can be seen from table 24 that with the Potato 342 and Tongo varieties no significant differences in numbers and weights of tubers were obtained between plants produced from tubers from high-yielding hills and those produced from tubers from low-yielding hills. No yield records were obtained for the Potato 592 and Potato 652 varieties, but observations made in the field during harvest indicated that much the same response was given by these two varieties.

TABLE 24.—*Yields of Potato 342 and Tongo yams in tests with seed tubers from high-yielding and low-yielding hills*

Variety and variable	Hills harvested	Average yield of tubers per hill	
Potato 342:	*Number*	*Number*	*Grams*
Plants from tubers of high-yielding hills	56	33. 2±1. 59	349. 1±18. 813
Plants from tubers of low-yielding hills	52	32. 8±1. 775	384. 2±27. 195
Difference	4	. 4±2. 39	35. 1±33. 068
Tongo:			
Plants from tubers of high-yielding hills	20	19. 5±2. 084	272. 7±43. 406
Plants from tubers of low-yielding hills	18	16. 5±1. 656	215. 0±32. 28
Difference	2	3. 0±2. 6618	57. 7±54. 09

FIGURE 21.—Tubers of Potato 592 yams typical of those used in shape-of-tuber propagation study.

All available evidence seems to indicate that, with the propagating material available in 1936, there was nothing to be gained from the use of tubers from high-yielding hills in preference to those from low-yielding hills provided the same size tubers were chosen for planting.

Field observations during harvest indicated that the same statements held true with respect to planting tubers of the same size from

hills containing many and hills containing few tubers for the Potato 659, Potato 592, Potato 324, and Tongo varieties.

Variations in shape of Potato yams could not be propagated.

Among the hills of Potato 592 yams harvested in February 1936 were observed hills in which all of the tubers were uniformly shorter and consequently proportionately thicker than was true for the tubers of the largest number of hills. Since there would be less waste in preparing these shorter tubers for cooking, a test was made with both kinds of tubers to determine whether this desirable shape could be propagated. Tubers typical of those used in this test are shown in figure 21. The results demonstrated that this short tuber shape could not be reproduced by vegetative propagation.

FIGURE 22.—Tubers from a hill of Potato 652 yams showing unusual growth conditions characteristic of all of the tubers in the hill. This tuberous growth character was not reproduced by vegetative propagation.

Early in 1936 one hill of Potato 652 yams was found in which all tubers bore small tuberous outgrowths on the upper portion near the stem end. Examples of these tubers are shown in figure 22. Results during the past year showed that this unusual variation could not be reproduced by propagation.

Extreme shapes in Morado yam tubers could not be propagated vegetatively.

Tests were made during the past year to determine whether certain extreme shapes in Morado yam tubers could be propagated. Ten distorted, rough tubers, so misshapen that they were unsuitable for human consumption, were planted in alternate hills with an equal number of smooth, symmetrical tubers. Tubers typical of the ones

used in this test are shown in figure 23. Results indicated that such shape variations could not be reproduced by propagation. The rough

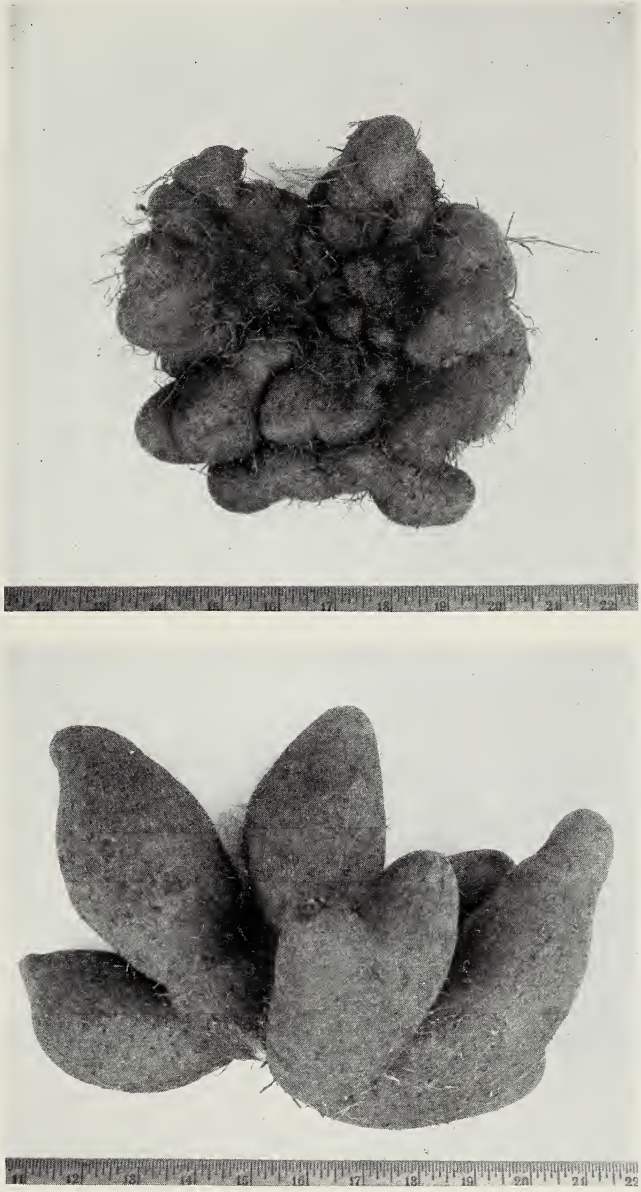

FIGURE 23.—Tubers of extreme shapes of Morado yams, typical of those which could not be reproduced by vegetative propagation.

tubers were apparently a result of poor physical condition of the soil in which they had grown.

Variations in numbers of lateral roots on Tongo yam tubers were apparently normal.

Tongo yam tubers are characterized by the rather long, somewhat stiff lateral roots on their surface. Some tubers were found that had few lateral roots. Ten of these tubers were planted in alternate hills of the same row with tubers that were covered with lateral roots. Results of the test indicated that these extreme conditions of lateral

FIGURE 24.—Tongo yam tubers showing extremes in development of lateral roots; these extremes of hairiness and nonhairiness could not be reproduced by vegetative propagation.

root development on Tongo yam tubers could not be reproduced in propagation. Tubers typical of those used in this test are shown in figure 24.

LIMA BEAN AND PEA VARIETY TESTS AND INSECT-CONTROL STUDIES

The field work in vegetable research has been conducted both on the lower fields of the experiment station and on the Las Mesas property. Las Mesas is at an altitude of 1,000 feet; the soils are of volcanic origin, granular, porous, and well-drained, but impoverished.

The lowland fields are only a few feet above sea level; the soil is of sedimentary origin, heavy clay, characterized by moderate fertility and poor drainage.

Lima beans were severely attacked by the lesser cornstalk borer at Las Mesas.

In a one-fifth-acre planting of the Challenger variety of lima beans made May 13, 1936, on recently cleared land at Las Mesas, well over 50 percent of the plants that came up were killed and many more of the plants were severely girdled by the feeding of the larvae of the lesser cornstalk borer, *Elasmopalpus lignosellus* (Zell.). Ninety percent is a conservative estimate of the proportion of the plants that were killed and injured by this pest.

A replicated planting of nine varieties of pole type limas and a replicated planting of eight varieties of the bush type made on June 18, 1936, adjacent to the above-mentioned Challenger planting were also seriously attacked by this insect. The proportion of the total number of plants to emerge following germination which was definitely known to have been killed and injured is shown for each variety of both types in table 25.

TABLE 25.—*Plants known to have been killed or injured by the lesser cornstalk borer, Elasmopalpus lignosellus (Zell.), in variety plantings of pole-type and bush-type lima beans on Las Mesas June 18, 1936*

Pole varieties	Plants killed or known to have been injured [1]	Bush varieties	Plants killed or known to have been injured [1]
	Percent		*Percent*
Burpee Best	54.35	Fordhook Bush	55.07
King of the Garden	51.55	Burpee Bush	48.37
Landreth Long Green Seeded	50.55	Improved Bush	44.80
Large Early Jersey	49.10	McCrea Bush Lima	43.37
Early Leviathan	47.30	Wood Prolific	34.90
Burpee Giant Podded	47.10	Burpee Philadelphia Bush	31.43
Carolina	46.05	Henderson Bush Lima	30.27
Burpee Sunnybrook	44.35	Jackson Wonder	26.43
Florida Butter Speckled	43.00		

[1] Averages of 4 plats.

Small-seeded type bush varieties showed partial resistance to lesser cornstalk borer.

No statistically significant differences existed among the pole types in the proportion of plants killed and injured by the lesser cornstalk borer, but there were significant differences among certain of the bush types. There was some indication that as a group the small-seeded or Sieva type bush varieties, Wood Prolific, Burpee Philadelphia Bush, Henderson Bush Lima, and Jackson Wonder were either more resistant or more tolerant to the feeding of the *Elasmopalpus* larvae than were the large-seeded bush varieties. However, in view of the fact that the true extent of the injury could not be ascertained because many of the plants which remained upright and continued growing and ultimately fruited were partially girdled, further confirmation is desirable. The most significant feature was that under the conditions of this planting and with the varieties tested, from 26.43 to 55.07 percent of all plants which came up were killed or definitely known to have been severely injured.

Lesser cornstalk borer damaged both garden peas and cowpeas.

In a replicated garden pea, *Pisum sativum*, variety planting made adjacent to the lima beans on Las Mesas and at the same time as the lima bean variety plantings, many pea plants were killed by the attacks of lesser cornstalk borer larvae. The proportion of the plants known to have been killed by these larvae is shown for each variety in table 26.

TABLE 26.—*Plants killed by the lesser cornstalk borer, Elasmopalpus lignosellus (Zell.), in a variety planting of garden peas, Pisum sativum, at Las Mesas June 18, 1936*

Variety	Plants killed [1]	Variety	Plants killed [1]
	Percent		*Percent*
Country	80.50	Roy Olunda Best	50.30
Horsford	74.57	Darjeeling	49.97
World's Record	63.87	Laxtonian	49.77
Thomas Laxton	60.70	Gradus	49.10
Laxton Progress	59.23	Admiral	39.83
Perfection	59.07	Alaska	29.97
Olunda	56.17	Alderman	25.73
Telephone	55.37		

[1] Averages of 3 plats.

Table 26 shows that the proportion of plants killed varied from 25.7 percent with Alderman to 80.5 percent with Country. As with the lima beans, this estimate of lesser cornstalk borer damage is in error, because many of the plants which continued growing nevertheless had been injured. That this undertermined injury was considerable is substantiated by the fact that a careful examination of all plants of the Alaska variety at harvest revealed that only 22 plants of a total of 627 were uninjured.

In addition to garden peas, lima beans, and dry beans mentioned in the 1936 annual report of the station, the lesser cornstalk borer severely damaged cowpeas, *Vigna sinensis*, planted on Las Mesas.

Lesser cornstalk borer devastated sweet corn planting at Las Mesas.

A 1½-acre planting of USDA–34 sweet corn, made on another recently cleared field of the Las Mesas property of the experiment station in May 1937 was almost completely wiped out by the lesser cornstalk borer. Not more than 5 percent of the plants survived to reach a height of 3 feet. An examination of the plants which did survive revealed that practically every stalk had been infested with the larvae.

No economical control measure is known for lesser cornstalk borer.

No effective economical control measure for the lesser cornstalk borer in bean, pea, and corn plantings is known. The larvae enter the stalks of the plants at the ground line and tunnel upward or in some cases girdle the stem at the ground line. Attempts to control this pest in lima bean and pea plantings by the use of paris green-bran-molasses bait were entirely unsuccessful.

The lesser cornstalk borer is not ordinarily considered a serious pest of beans, peas, and corn in Puerto Rico. Research employees of the Bureau of Entomology and Plant Quarantine stationed in Puerto Rico stated that such serious outbreaks of insect pests on crops planted in freshly cleared land in an area where the land has not been in cultivation for a long period of years are not uncommon and that under

such conditions the infestations usually decrease in intensity over a period of several years until they approach the normal for that general section of the country and the particular insect involved.

The melon worm was a serious pest of calabazas and muskmelons.

Other insect pests which were of importance on vegetable plantings during the year were the black cutworm, *Prodenia ornithogalli* Guenée, which seriously damaged garden peas on Las Mesas, and the melon worm, *Diaphania hyalinata* (L.), which seriously damaged calabaza plantings on Las Mesas, and muskmelon and cucumber plantings both on Las Mesas and on the lowland property of the experiment station. Watermelons planted adjacent to infested cucumbers and muskmelons were not attacked by the melon worm.

Blossom drop of large-seeded lima beans was heavy during the summer months.

Blossom drop of large-seeded lima beans has been reported as being not an uncommon occurrence in many places in Puerto Rico during the summer months in spite of the moderate equable temperature and constantly high relative humidity. Evidence indicates that this heavy blossom drop of lima beans during the summer cannot be attributed entirely to unfavorable weather conditions, at least in the Mayaguez section of the island. A one-fifth-acre planting of the Challenger variety made on Las Mesas in May 1936 failed to produce any appreciable quantity of beans until early in October, although the plants grew vigorously and blossomed profusely beginning the latter part of June. The abscission of blossom buds, blossoms, and young pods was heavy throughout July, August, and most of September, so heavy that prior to October 10 an average of less than one pod per plant or a total of less than 20 pounds of pods had been harvested from the entire area.

Bean pod borers were a factor in abscission of buds, blossoms, and young pods.

Frequent examinations of abscised buds, blossoms, and small pods revealed that many of the buds and blossoms and practically all of the young pods had been or still were infested with larvae of bean pod borers. Many buds, blossoms, and young pods still attached to the plants were observed to be so infested; and of those pods which did not abscise before harvest, approximately 32 percent were found to be infested with one or more larvae. The increase in production which occurred during the early part of October was associated with a smaller infestation, beginning the latter part of September. Changing climatic conditions could hardly have been much of a factor in this increased production, for there is little or no difference in the temperature in Mayaguez during June, July, August, September, and October, and rainfall was abundant during the entire period.

Heavy October harvests are normal for beans in western Puerto Rico.

According to people who live in the rural areas in this section of the island, a marked increase in production is normal for all types of beans during October in the vicinity of Mayaguez. The suggestion is offered that the big October crop of beans in this part of the island might be closely associated with and largely a result of a seasonal decrease in pod borer infestation.

Infestation of lima bean plantings by pod borers of much the same severity as obtained on Las Mesas during the summer months has

been reported for the region around Cidra in the interior of the island.

Of the three pod borers, *Maruca testulalis* (Geyer), *Fundella cistipennis* (Dyar), and *Etiella zinckenella* (Treitschke), which are known to infest cultivated beans in Puerto Rico, larvae of *Maruca testulalis* were by far the most prevalent, constituting approximately 85 percent of the entire pod borer population.

Bean pod borers did not infest pods of garden peas, although the peas were planted adjacent to the infested lima beans on Las Mesas.

Derris powder sprays were ineffective in controlling bean pod borers.

In tests with Challenger lima beans mentioned above, derris sprays consisting of derris alone and in combination with other insecticides were found to be ineffective in controlling bean pod borers. The beans were planted May 13 and were blooming profusely by July 15. Seven applications of each spray combination were made from July 23 to September 10. Two months after spraying was begun less than 20 pounds of green beans in the shell had been produced on the whole fifth-acre in the test; furthermore 32 percent of the pods harvested were infested with pod borer larvae. The check plats gave the highest yields. During the whole period of the spray applications the ground beneath the plants was covered with abscised blossom buds, blossoms, and young pods, many of the buds and blossoms and practically all of the pods of which either were or had been infested with pod borers.

There were six replicated plats for each of the six insecticidal treatments and the check. The insecticides were derris alone, derris in combination with fish oil, derris plus a commercial sticker and spreader, derris with nicotine sulphate and soap, derris with a proprietary organic thiocyanate insecticide and a commercial sticker and spreader, and a proprietary organic thiocyanate insecticide and a commercial sticker and spreader without derris.

Wild lima bean was reported free from pod borer infestation.

It had been observed by research investigators of the Bureau of Entomology and Plant Quarantine stationed at Mayaguez that the pods of a wild lima bean found growing in various parts of the island were never infested with pod borer larvae, even though the plants were growing and fruiting along the edges of fields of severely infested cultivated beans. As a result of this observation it seemed possible that certain of the cultivated varieties of lima beans might show some resistance to or be entirely immune to pod borer infestation, especially since the pods of certain of the small-seeded or Sieva type limas resemble the pods of the Puerto Rican wild lima rather closely in texture and appearance.

Comparative susceptibility of 17 cultivated varieties of lima beans to pod borers.

On June 18, 1936, a lima-bean-variety planting consisting of the following varieties was made on Las Mesas:

SMALL-SEEDED VARIETIES

Pole type:
- Carolina.
- Florida Butter Speckled.

Bush type:
- Henderson Bush Lima.
- Jackson Wonder.
- Wood Prolific.
- Burpee Philadelphia Bush.
- McCrea Bush Lima.

LARGE-SEEDED VARIETIES

Pole type:
- King of the Garden.
- Landreth Long Green Seeded.
- Large Early Jersey.
- Burpee Giant Podded.
- Burpee Sunnybrook.
- Burpee Best.
- Early Leviathan.

Bush type:
- Burpee Bush.
- Fordhook Bush.
- Burpee Improved Bush.

This planting was so severely damaged by larvae of the lesser cornstalk borer and by leafhoppers that an accurate comparison of the possible resistance of the varieties to pod borer infestation could not be made, although the following statements seem justified.

None of the varieties tested was immune to pod borer infestation.

No variety was found to be entirely immune to pod borers. When considered on the basis of the proportion of the pods infested, the infestation of small-seeded sorts was consistently much smaller than that of large-seeded types. But when infestation was considered on the basis of land area occupied, there appeared to be no consistent differences among the varieties in extent of infestation as measured by the number of pods containing larvae when harvested. A reasonably accurate estimate of the comparative severity of blossom bud, blossom, and small-pod abscissions as a result of pod borer infestation among the varieties was not obtained.

The leafhopper was a severe pest of lima beans.

In the annual report of this station for 1936 it was pointed out that the leafhopper, *Empoasca fabalis* DeLong, was a serious pest of dry beans in the lowland fields at the experiment station. This was true during the past year also with lima beans on Las Mesas. Many plants of the bush varieties were killed and practically all plants of both bush and pole types were severely defoliated as a result of the feeding of this insect. A bordeaux mixture-nicotine sulphate spray failed to effect a satisfactory control over the leafhoppers as did also a recommended proprietary organic thiocyanate contact insecticide. However, they were controlled effectively by a pyrethrum-soap spray when repeated applications were made at 10-day intervals.

These insect-control problems and the variety tests for resistance to insect infestation constituted a joint project of this station and the Bureau of Entomology and Plant Quarantine with L. B. Scott, associate entomologist, cooperating.

Thirty-one varieties of lima beans were tested during the winter for pod borer infestation.

As a further more extensive test of the possibility of certain cultivated varieties of lima beans being resistant to or immune from pod borer infestations, a well-replicated variety planting consisting of 18 varieties of pole limas and 13 of bush limas was made on an irrigated section of the lowland property of the experiment station December 29 and 30, 1936. Each replication consisted of a single-row plat 25 feet long. The rows were 2.5 feet apart. With the bush varieties the hills were spaced 6 inches in the row with 2 plants per hill, and for the pole varieties the hills were 15 inches apart with 2 plants per hill. There were 11 replications of the pole varieties and 6 replications of the bush types. The varieties were arranged at random within each replication

group, and the blocks or replication groups of the two types of varieties were alternated down the field until the seed supply of the bush varieties became exhausted. There were short guard sections at both ends of the field and two guard rows extending down both sides of the field.

Pod borer infestation was small for all varieties during the winter.

Seven harvests were made, the first on March 3 and the last on April 15. Satisfactory yields were obtained with 30 of the 31 varieties. As indicated by the number of infested pods at harvest, pod borer infestation was so small as to be of slight commercial importance. Again, as on Las Mesas, no variety was entirely free of occasional infested pods. Very few buds, blossoms, and young pods were found that had abscised because of pod borer infestation.

The varieties included in this planting are listed in table 27.

TABLE 27.—*Yield of green beans for lima-bean-variety planting made Dec. 29 and 30, 1936, on lowland property of the experiment station*

[Varieties are listed by types and in the order of their production within each type]

Types and varieties [1]	Beans in the shell per acre [2]	Pods per pound of beans in the shell [3]	Developed ovules per typical pod [4]	Ovules per ounce of shelled beans [5]	Waste in shelling [6]
Pole varieties:					
Large-seeded type:	*Bushels*	*Number*	*Number*	*Number*	*Percent*
Early Leviathan	533	37.8	3.5	14.2	53.8
Ford Mammoth	524	39.8	3.3	14.0	55.3
Burpee Sunnybrook	512	40.1	3.5	14.0	54.4
Siebert Early	481	53.4	3.2	16.5	52.5
Carpinteria	473	40.9	3.4	16.4	58.4
Detroit Mammoth Lima	469	40.1	3.4	16.0	55.1
Burpee Giant Podded	465	39.4	3.6	16.1	56.8
Dreer Improved Pole	464	48.8	3.4	16.5	53.7
Henderson Ideal	458	39.1	3.9	16.0	57.7
King of the Garden	449	39.8	3.2	15.7	57.4
Giant Podded Pole Lima	444	30.6	4.6	15.3	54.4
Burpee Best	423	39.8	3.3	16.7	57.1
Challenger	347	49.3	3.5	17.9	53.9
Sieva type:					
Hopi Lima	276	141.7	2.7	50.9	62.1
Carolina or Sieva	239	141.7	2.6	47.1	54.6
Florida Butter Speckled	227	119.4	2.7	43.5	55.3
Southern Willow Leaf	203	133.4	2.7	53.2	60.7
Bush varieties:					
Large-seeded type:					
Burpee Bush	424	50.4	----------	16.8	59.2
New Wonder Bush	378	51.0	----------	18.0	60.8
Henderson Early Giant	372	72.0	----------	20.0	63.2
Burpee Improved	344	44.5	----------	16.7	61.6
Burpee Fordhook	323	51.7	----------	19.2	59.6
Dreer Bush	298	54.6	----------	19.2	58.0
Kilgore New Marvel	298	75.6	----------	13.8	68.2
Dreer Wonder Bush	271	52.1	----------	17.2	60.0
Sieva type:					
Jackson Wonder	259	116.3	----------	44.0	62.7
McCrea Bush Lima [7]	247	84.0	----------	43.6	[8] 72.4
Burpee New Philadelphia	210	90.7	----------	43.8	72.0
Improved Henderson	210	108.0	----------	48.5	67.8
Henderson	193	137.5	----------	51.5	62.1

[1] Monstrous Lima not included; blossomed late and sparingly and produced few pods.
[2] 32 pounds per bushel. Averages for pole varieties based on yields of 9 plats; for bush varieties, on yields of 5 plats.
[3] Calculated from average weight per pod, based on total harvest.
[4] Averages based on means of 4 500-gram typical pod samples for each variety Apr. 9 harvest. Data unavailable for bush varieties.
[5] Averages based on 4 500-gram pod samples from Apr. 2 and 4 500-gram samples from Apr. 9 harvests.
[6] Averages based on 8 500-gram pod samples, 4 from Apr. 2 and 4 from Apr. 9 harvests.
[7] Small-seeded, but probably not true Sieva type.
[8] Ovules somewhat young for accurate comparison with other varieties.

Leafhoppers preferred feeding on the thin glossy foliage of the small-seeded varieties.

The planting was infested with a large population of bean leafhoppers, *Empoasca fabalis* DeLong. The leafhoppers seemed to prefer feeding on the thin glossy leaves of the plants of the small-seeded varieties rather than on the less glossy, thicker leaves of the large-seeded sorts. The plants of the large-seeded sorts were considerably larger, but a much greater number of insects per plant was observed on the smaller plants of small-seeded types. Insofar as could be ascertained, leafhoppers did no appreciable damage to the plants of large-seeded varieties; at least the damage was not severe enough to cause premature defoliation.

Feeding of leafhoppers caused premature defoliation of small-seeded lima bean varieties.

With all small-seeded varieties leafhopper injury was severe. Visible effects were first a turning down of the edges of the leaves, giving them a cupped appearance, followed soon by a yellowing of the margins of the leaves. This yellowing of the leaf margins progressed toward the centers of the leaves until in the most advanced stages most of the chlorophyll of the leaves had either been destroyed or was masked, giving the leaves a yellow mottled appearance. A large proportion of the leaves of the small-seeded-type plants abscised prematurely. That this observed yellowing or mottling of the leaves was directly associated with the feeding of the insects and not with a virus disease of which the leafhoppers might be a vector was strongly indicated by the fact that the secondary leaf growth occurring on the partially defoliated plants of the small-seeded varieties, after the peak of the leafhopper infestation had passed, did not show the characteristic yellowing and mottling that was observed on the leaves of the primary growth of the same plants.

It is possible that the plants of the large-seeded lima beans would have been attacked in larger numbers by leafhoppers if the plants of the small-seeded sorts had not been available to them.

The Early Leviathan variety produced 533 bushels of green beans per acre.

This experiment was not planned to test the relative productiveness of the lima bean varieties. While the number of replications and the location of varieties within replication blocks were satisfactory for such comparisons, the single-row plats with the rows only 30 inches apart made for so much competition, especially among the pole types, that where a large-growing vigorous variety was planted adjacent to a smaller less vigorously growing variety, the difference between these two varieties would tend to be greater than if the plants of each variety were surrounded by plants of its own kind. The average yield of pods for the different varieties, as shown in table 27, then, should not be considered as an accurate indication of the yields that these varieties may be expected to produce when each is planted in separate blocks in commercial quantities.

However, the yields are of particular interest because the level of production of such a large proportion of the varieties was so high. This was especially true for the large-seeded pole sorts. It can be seen from table 27 that none of the large-seeded pole varieties yielded

less than an average of 347 bushels of pods per acre, and only one variety averaged less than 423 bushels, while three varieties yielded more than 500 bushels, with 533 bushels per acre the average yield of the highest yielding variety. With the large-seeded pole varieties there were no statistically significant differences among Early Leviathan, Ford Mammoth, Burpee Sunnybrook, Siebert Early, Carpinteria, Detroit Mammoth Lima, Burpee Giant Podded, Dreer Improved Pole, Henderson Ideal, and Giant Podded Pole Lima. All varieties except Burpee Best were significantly superior to Challenger. Only Early Leviathan and Ford Mammoth were significantly superior to Burpee Best.

Large-seeded pole varieties were heavier producers than small-seeded pole sorts.

The large-seeded pole varieties were significantly superior in production to the small-seeded poles except that there was no significant difference between Challenger and Hopi Lima.

With bush varieties the differences in yield between the large-seeded and the Sieva types were less definite statistically, for only the four highest yielding large-seeded bush varieties were significantly superior to all small-seeded varieties. With the large-seeded bush sorts the yields varied from 271 bushels per acre for Dreer Wonder Bush to 424 bushels per acre for Burpee Bush. Among the large-seeded bush, Burpee Bush was significantly superior to all others except New Wonder Bush and Henderson Early Giant. Excluding Burpee Bush, New Wonder Bush was significantly superior to all varieties except Henderson Early Giant, Burpee Improved, and Burpee Fordhook. There were no significant differences in yield of pods among Burpee Improved, Burpee Fordhook, Dreer Bush, Kilgore New Marvel, and Dreer Wonder Bush.

There were no significant differences among yields of the small-seeded varieties.

With the small-seeded sorts there were no statistically significant differences among pole varieties, among bush varieties, or between any of the pole and bush varieties. The average yields per acre varied from 193 bushels with Henderson to 276 bushels with Hopi Lima.

Pole varieties produced a higher quality product than did bush varieties.

The pole varieties as a group produced a much higher quality product for market than did the bush types. The pods of the pole sorts were clean and relatively free from pod diseases, while many of the pods of the bush type were covered with soil and affected with pod spots.

The three varieties giving the highest total yield, Early Leviathan, Ford Mammoth, and Burpee Sunnybrook, also produced the largest beans as indicated by the average number of ovules per ounce of shelled beans.

These three varieties were also among those that gave a comparatively small percent waste in shelling. As a group the large-seeded bush varieties were found to give a somewhat larger proportion of waste in shelling than the large-seeded pole sorts. The most significant point with regard to waste in shelling was that the loss was so great; the smallest average recorded was 52.5 percent.

Green lima beans brought good prices in New York during the past winter.

In connection with the yield figures in table 27 the prices quoted on the New York market for lima beans each week on the day that refrigerated shipments from Puerto Rico were offered for sale during the period of harvest for this planting, are of interest. These prices as obtained from the miscellaneous fruit and vegetable reports of the Bureau of Agricultural Economics of the Department of Agriculture are shown in table 28.

TABLE 28.—*Wholesale prices per bushel for lima beans on New York market at weekly intervals during the spring of 1936 when refrigerated Puerto Rican produce was offered for sale*

Date	Minimum quotation	Minimum quotation for excellent quality Cuban beans [2]	Maximum quotation for excellent quality Cuban beans [2]	Maximum quotation
Mar. 9	$2.00	$3.00	$4.00	$4.50
Mar. 16	2.50	3.25	4.00	4.50
Mar. 24 [1]	2.25	3.25	4.25	5.00
Mar. 30	2.00	3.00	4.00	4.75
Apr. 6	2.00	3.00	3.50	3.50
Apr. 13	2.00	3.50	4.00	4.50
Apr. 20	3.00	4.50	4.75	4.75
Average for the period	2.25	3.36	4.07	4.50

[1] Quotations for Mar. 23 unavailable; Mar. 24 used as substitute.
[2] Quotations for Cuban beans when available.

Good prices for green limas are not unusual during the winter and early spring months when the commercial crop would be harvested in Puerto Rico. In view of these facts and the uniformly high yields secured from most varieties under the conditions of this test, it would seem that further experiments in the production of these beans, especially the large-seeded pole types, for winter markets would be warranted.

TURNIP-VARIETY TEST

Two varieties of turnips gave excellent results during the winter.

At low elevations the temperatures in Puerto Rico, even during the winter months, are somewhat higher than those under which turnips are known to thrive and under which their roots attain the highest eating quality. However, of four varieties of turnips planted on the Las Mesas property of the experiment station during the winter of 1936–37, two were found which produced roots of excellent quality. Comparative eating-quality tests were made with both raw and cooked roots. The roots of Kilgore Tokyo Market and Early White Flat Dutch varieties had a strong bitter taste which made them unpalatable in both the raw and cooked state. On the other hand, the roots of the Japanese Foliage turnip and the Purple Top White Globe were mild and sweet and of excellent quality both raw and cooked. In Puerto Rico, where there is such a dearth of green leafy vegetables in the diets of most people, the Japanese Foliage turnip would seem to be valuable, for it produces a heavy yield of upright-growing, aphis-resistant foliage that can be used as greens if harvested before the leaves become too mature.

CAMP GARDEN WORK

Cooperative vegetable garden work with Puerto Rico Reconstruction Administration.

Early in October 1936 a vegetable-gardening project was organized at Camp El Caribe of the Puerto Rico Reconstruction Administration, which is located on the Las Mesas property of the experiment station. The camp personnel was composed of about 250 men, approximately 200 of whom were field laborers.

The purpose of this gardening project was twofold: (1) To enable the men to obtain, under competent direction, actual experience in all phases of the production of vegetables, both those that are commonly grown in the island and others which are not commonly grown but which can be produced successfully and which would be desirable additions to the diet; and (2) to introduce these new vegetables into the diet of the men by showing methods of preparation and by serving such vegetables properly cooked.

This work was placed under the unofficial supervision of the experiment station, and the project was closely coordinated with the vegetable-research program of the station.

An effort was made to afford the men as wide a range of experience as possible, and they were rotated weekly and bimonthly in groups of 10 to 20 each, the size of the group depending upon the nature and extent of the work to be done. The men showed interest in this work.

New vegetables were introduced in the diet at Camp El Caribe

Among the products that were made available for consumption at the camp as a result of this project were a number of vegetables which are not commonly eaten by the small farmers of the island. These "new" vegetables were green lima beans, sweet corn, green peppers, cucumbers, summer squash, green onions, radishes, carrots, beets, turnips, turnip greens, mustard spinach, swiss chard, and collards. The lima beans, sweet corn, green peppers, cucumbers, summer squash, green onions, radishes, carrots, and beets, when they were suitably prepared, were relished by most of the men; and some of them professed to like the green, leafy vegetables after having eaten them several times. Surplus bananas, plantains, and grapefruit from station plantings were made available to the camp for consumption in connection with this gardening project. On several occasions when more produce accumulated than could be consumed at Camp El Caribe the surplus was sent to other Puerto Rico Reconstruction Administration camps of the island.

Twenty-four different kinds of produce were furnished to Camp El Caribe.

The total quantities of each of the 24 different kinds of produce which were made available to the camp for consumption from this vegetable-gardening project during the 8 months from the time of its organization in October 1936 to May 1, 1937, are shown in table 29:

TABLE 29.—*Produce from the vegetable-gardening project delivered to El Caribe Camp and other Puerto Rico Reconstruction Administration camps for consumption between Oct. 7, 1936, and May 1, 1937*

Produce	Quantity	Unit	Produce	Quantity	Unit
Bananas	121	Racemes.	Onions, green	4,300	Bulbs.
Green lima beans	3,758	Pounds.	Peppers	180	Pounds.
Green lima beans, shelled	198	Do.	Plantains	13,770	Fingers.
Beets	300	Roots.	Radishes	32,270	Roots.
Calabazas	641	Pounds.	Sweet corn	9,979	Ears.
Carrots	2,610	Roots.	Sweetpotatoes	2,203	Pounds.
Chayotes	83	Pounds.	Swiss chard	330	Do.
Collards	150	Do.	Summer squash	1,865	Do.
Cucumbers	3,584	Do.	Tomatoes	72	Do.
Gandules	340	Do.	Turnips	950	Roots.
Grapefruit	1,045	Fruits.	Turnip tops	100	Pounds.
Mustard spinach	300	Pounds.	Yams	3,464	Do.
Onions, dry	293	Do.			

Sweet corn seed was furnished to the Puerto Rico Reconstruction Administration.

In addition to the produce made available to the camp for consumption, the garden-project activities resulted in 132 pounds of USDA–34 sweet corn seed being made available to the Gardening and Poultry Unit of the Land Utilization Section of the Puerto Rico Reconstruction Administration for planting at other camps, thereby supplementing the 500 pounds of sweet corn seed that had been made available earlier in the year.

All of the foregoing studies of vegetable crops have been conducted by Wallace K. Bailey, associate plant physiologist.

INVESTIGATIONS OF INSECTICIDAL PLANTS

Many introductions of insecticidal plants are now established at the experiment station.

During the year, through the cooperation of the Division of Plant Exploration and Introduction of the Bureau of Plant Industry, three shipments of insecticidal plants, including two additional introductions of *Tephrosia toxicaria* seed, were added to the collection already growing in station fields. Of these three shipments 1,436 specimens survived and became established in the station collection. For the previous year 160 introductions had become established; as many of these were duplicated in the three shipments of the past year, the total number of unrepeated introductions which are now well established has been increased to 205 at the present writing.

Propagation of introductions has filled three needs: (1) It has maintained a stock of living plants of those species already harvested so that they will be available should they prove of insecticidal value; (2) it has increased the number of plants from introductions having insufficient plants at the beginning to provide enough bulk for harvest; (3) in addition it has been used to provide material for agronomic tests. Thirty-three introductions representing 23 genera were propagated from cuttings and produced 3,763 plants, of which 3,275 were *Derris elliptica* variety Sarawak Creeping. Eighty-three introductions were raised from seed and supplied 3,550 plants representing 31 genera.

Samples of plant components were shipped to Washington for toxicological studies.

Whenever possible, introductions of insecticidal plants were not harvested until they approached maturity. Harvesting consisted of separating the plants into easily divisible components such as roots, stems, and leaves, and also flowers, green and ripe fruits, and seeds when the latter were available. These fractions were coarsely ground, air-dried in indirect light, compacted in a hydraulic press into small bales weighing from 4 ounces to about 1 pound, and shipped to the Bureau of Plant Industry and later transferred to the Bureau of Entomology and Plant Quarantine in Washington for toxicological studies. In addition to the investigation of insecticidal value, Washington collaborators have been making chemical analyses on certain of the species known to contain rotenone.

Two hundred and ninety-six bales were shipped, representing 79 plant introductions. Fifty-seven of the latter were received through the Division of Plant Exploration and Introduction, 20 were collected in Puerto Rico, 1, *Amorpha fruticosa,* in Nebraska, and 1, *Sesban* sp., was raised from seed received from Barakat, Egypt.

The Durham test was negative for a majority of the plants studied.

At the time of harvest of each plant introduction, the Durham test for rotenone and certain of its allied compounds was applied to specimens of each plant component. Of the 79 representatives of 48 genera tested, those of 42 genera were completely negative. The genera giving positive reactions were *Calopogonium, Amorpha, Aeschynomene, Tephrosia, Derris,* and *Lonchocarpus.*

Of the three species of *Calopogonium* indigenous to Puerto Rico, *C. orthocarpum* and *C. coeruleum* have been tested and were found to give a positive reaction only in the hypocotyl of the seed. The species *Amorpha fruticosa* indigenous to the Mississippi Valley, gave a moderately positive reaction in the roots, a somewhat more pronounced reaction in the underground stems, a slightly positive reaction in the bark of the aerial stems, and a strong reaction in the seed. *A. fruticosa* and the two species of *Calopogonium* have not previously been reported to contain rotenone. *Aeschynomene sensitiva,* collected at the station, was strongly positive in the seed.

Leaves and stems of Tephrosia vogelii gave a positive reaction to the Durham test.

Two introductions of *Tephrosia* (*Cracca*) *vogelii* have been the only plants tested thus far to give a distinctly positive reaction in the leaves and young stems. Because of the thinness of the leaf, the color test was more transient in this organ than it was in thicker tissues, such as stems, roots, and seeds of other species.

The harvesting of such insecticidal plants as *Derris* and *Lonchocarpus* is expensive inasmuch as the insecticidal properties of these plants are contained in the roots, principally the smaller roots. Any species containing the insecticidal properties in the leaves or above-ground stems will have a considerable advantage in economy of harvest as compared with such root crops as *Derris* and *Lonchocarpus.*

Tephrosia vogelii, which grows from seed, also has some slight advantage in economy of cropping over plants grown from cuttings, such as *Derris* and *Lonchocarpus. T. vogelii* at Mayaguez has grown to its maximum development of leaves in 5 to 6 months, whereas from 18

to 24 months are required for *Derris* species and even 4 years has been mentioned in the literature for the time of maturity of *Lonchocarpus*. *T. vogelii* has usually grown 6 to 7 feet high with abundant foliage without fertilizers in the experiment station fields.

For these reasons the positive Durham test in the leaves of *T. vogelii* is of more than casual significance, for with these advantages, even with lower concentrations, it may produce rotenone more cheaply per unit than *Derris* or *Lonchocarpus*.

Lonchocarpus and Derris species have best promise as rotenone producers.

Chemical determinations made by the Division of Drug and Related Plants of the Bureau of Plant Industry on the roots from individual plants were reported as follows:

	Percent rotenone
Lonchocarpus nicou, Plant Introduction No. 97923, from Peru	7. 89
Lonchocarpus nicou, Plant Introduction No. 97923, from Peru	10. 23
Lonchocarpus spp., from Peru, Brazil, and the Guianas	0. 96–5. 13
Derris elliptica, variety Sarawak Creeping	4. 46
Derris elliptica, variety Changi No. 3	4. 16

Although the two plants of Peruvian *Lonchocarpus nicou* were 2 years old when the roots were harvested, the plants were only about 30 inches high, having been grown under adverse soil and climatic conditions. The figures for percentages of rotenone in *Lonchocarpus* spp. represent the range found in a field of a local grower interested in raising *Lonchocarpus* commercially. The original propagating stock of this collection comprises at least several species which were obtained in South America. These plants had been grown in an unusually favorable environment and were 1 year and 9 months old when harvested. The roots of the two varieties of *Derris elliptica* were taken from plants a little over 3 years old. As the concentration of rotenone in the roots has been reported to decrease after the end of the second year, the determinations given are probably somewhat less than they would be for younger roots.

Formaldehyde treatments controlled damping-off in Tephrosia.

A high percentage of mortality and even complete loss of seedlings has been found to result when plants of the *Tephrosia* species were started from seed. This handicap has proved especially serious when only a few seeds of a new introduction of *Tephrosia* are available for propagation. An experiment was therefore undertaken to test the value of several recommended treatments for soil in which *Tephrosia* seedlings were to be started in the hope that survival after germination could be improved.

In the experiment four flats filled to a depth of 3 inches with potting soil were allotted to each treatment. The treatments were as follows: Treatments A and D tested the use of two proprietary compounds recommended to control damping-off; directions for their use were followed in detail. Treatment B was a control with no treatment. In treatment C each of the four flats was given a 2-liter application of 0.05-percent potassium permanganate solution and then covered with heavy wrapping paper for a period of 4 days prior to seeding. In treatment E, by means of circulating air heated directly with steam the soil in the flats was raised to 125° F. and held at this temperature for 3½ hours. After an interval of 4 days the same treatment was repeated. As soon as the soil had cooled, the flats were seeded.

In treatments F and G formaldehyde solution was used at two strengths, 0.05 and 0.10 percent, respectively. Each formaldehyde-treated flat was given a 2-liter application of its respective solution and then covered with heavy wrapping paper for 4 days prior to seeding.

In order to make feasible the accurate counting of the seedlings, it was necessary to have them emerge from the soil as nearly simultaneously as possible, or death by damping-off would introduce error before germination was complete. To meet this need, the seeds of *Tephrosia toxicaria*, Plant Introduction No. 107462, were immersed in concentrated sulphuric acid for 15 minutes, flushed free of acid by means of water, and allowed to swell in tap water overnight. Only swollen seeds were planted.

Steam and formaldehyde treatments successfully controlled damping-off.

In previous experience it was noted that a dense stand of seedlings seemed to favor the development of damping-off by impeding air movement and shading the soil. In order to provide good damping-off conditions for this experiment, therefore, the seedlings were crowded by planting 100 seeds in each 21-inch row, and five rows were planted per flat. To give the fungus the greatest possible advantage, the surface of the soil was kept moist with filtered tap water for the first 5 days after seeding. At the end of the 5-day period the soil surface was allowed to dry in order to obviate the loss of all seedlings in infected flats.

Because of the pretreatment with acid and the planting of only swollen seeds, practically all the seedlings emerged between the third and fifth days after seeding. Counts of total emergence on the fifth day are given in table 30. Only an occasional seedling was observed to emerge after this record had been taken. The final count of healthy seedlings was made on the fourteenth day after seeding, inasmuch as it had previously been observed that little injury by damping-off occurred subsequent to 10 to 14 days after seeding.

TABLE 30.—*Percentages of germination, and subsequent losses from damping-off in an experiment to determine the value of soil treatments in the control of damping-off in Tephrosia seedlings*

Treatment	Total emerged seedlings, fifth day[1]		Surviving plants, fourteenth day		Losses by damping-off, fourteenth day
	Number	*Percent*	*Number*	*Percent*	*Percent*
A. Proprietary compound No. 1	1,159	58.0	261	13.1	86.9
B. Control	1,202	60.1	379	19.0	81.0
C. 0.05 percent potassium permanganate	1,441	72.1	398	19.9	80.1
D. Proprietary compound No. 2	1,492	74.6	682	34.1	65.9
E. Steamed	1,778	88.9	1,523	76.2	23.8
F. 0.05 percent formaldehyde	1,877	93.9	1,585	79.3	20.7
G. 0.10 percent formaldehyde	1,859	93.0	1,770	88.5	11.5

[1] Because of the rapid disintegration of seedlings killed by damping-off, accurate counts of total emergence were impossible after the fifth day. Percentages for emerged seedlings and surviving plants were calculated on the basis of the 2,000 seeds planted for each treatment.

Biometric analysis of counts made on the fourteenth day separated the treatments into two well-defined groups. Calculations showed

the steam and two formaldehyde treatments to have a highly significant superiority over all other treatments, but the number of replications was insufficient to rank these better treatments as to relative merit. Similarly no significant differences existed between the remaining four treatments, with the possible exception of a scarcely significant difference between the control and proprietary compound No. 2. The statistical analyses for this experiment were made by A. N. Watson.

Economy of application favored the use of formaldehyde.

Although no statistically significant differences between the steam and formaldehyde treatments were evident from the results reported here, formaldehyde as a control for damping-off in *Tephrosia* was preferred to steam treatment because it required less labor, time, and equipment.

Pod borer infestation of Tephrosia species showed seasonal trends.

Casual observation had indicated that the percentage of pods of *Tephrosia toxicaria* infested by insects was highest during summer and lowest in winter. To obtain a record of the trends of infestation over a period of months, counts were made of healthy and infested mature pods produced by two small adjacent plantings showing distinct varietal differences.

Pods were classified as infested when frass was found in them, only a few of such having been observed to contain larvae or pupae. All pods of small harvestings were examined. When the number of pods of a harvest was large, they were thoroughly mixed and from 20 to 35 samples of 10 pods each were removed for examination. Table 31 does not include all the records taken, but consists of part of the original records and illustrates the seasonal trends of infestation.

TABLE 31.—*Seasonal trends of infestation of Tephrosia toxicaria by pod borers*[1]

Date of harvest	*T.* (*Cracca*) sp.,[2] Introduction No. 110849		*T. toxicaria*, Introduction No. 110918	
	Pods harvested	Pods infested	Pods harvested	Pods infested
	Number	*Percent*	*Number*	*Percent*
June 17, 1936	29	100	[3]	
July 29, 1936	204	86	50	100
Sept. 3, 1936	1,830	[4] 13	45	36
Oct. 13, 1936	1,181	[4] 6	15	33
Oct. 28, 1936	1,623	[4] 3	850	[4] 2
Dec. 12, 1936	428	[4] 2	5,600	[4] 1
Jan. 4, 1937	130	13	21,606	[4] 4
Feb. 9, 1937	414	3	2,300	[4] 2
Feb. 27, 1937	294	5	2,430	[4] 4
Mar. 18, 1937	26	31	900	[4] 8
Apr. 14, 1937	150	39	2,900	[4] 26
May 29, 1937	677	[4] 47	814	[4] 54
June 12, 1937	611	[4] 46	140	65
June 26, 1937	468	[4] 71	[3]	

[1] Identified as *Brachyachma palpigera* (Wlsm.) and *Etiella zinckenella* (Treitschke) by Plank.
[2] This introduction appears to be identical with others received as *Tephrosia toxicaria*.
[3] None ripe.
[4] Percentages are based on sample counts.

As the data shown in table 31 developed, the first impression received was that the percentage of pods infested varied inversely

with the number of pods produced. However, during the succeeding winter, as will be noted in the table, although few pods ripened on one introduction and many on the other, the percentages of infested pods retained their relative magnitudes for both. The correlation that appears more probable is that the infestation is less during the winter months of dry weather, and heaviest during the summer months of slightly higher temperatures but much greater rainfall and atmospheric humidity.

Varieties of Derris elliptica were cross-pollinated.

It had been observed that vigorous plants of the Sarawak Creeping and Changi No. 3 varieties of *Derris elliptica* when 3 years old produced an abundance of flowers, but that few pods formed and matured. Preliminary work had demonstrated that if the 40 or more buds in a cluster were allowed to develop into flowers, scarcely any or none of them would form pods regardless of whether they were naturally pollinated, artificially selfed, or cross-pollinated. However, if all but two to four of the buds were removed when the inflorescence began to elongate, the percentage of flowers which developed pods was notably increased, thus greatly reducing the labor involved in seed production through artificial pollination.

A test on artificial selfing and cross-pollination, carried out near the close of the blooming season with 3-year-old plants, yielded the results shown in table 32.

TABLE 32.—*Results of pollination in varieties of Derris elliptica*

ARTIFICIAL SELFING

Variety	Flower clusters	Flowers selfed	Flowers that matured pods	
	Number	*Number*	*Number*	*Percent*
Sarawak Creeping	10	[1] 20	3	15.0
Changi No. 3	10	[1] 20	0	.0

CROSS-POLLINATION

Crosses made		Flower clusters	Total crosses	Flowers that matured pods	
Pistillate parent	Staminate parent				
		Number	*Number*	*Number*	*Percent*
Sarawak Creeping	Changi No. 3	16	52	5	9.6
Changi No. 3	Sarawak Creeping	18	72	11	15.3

[1] Two flowers in each cluster.

As a test of technique, four buds on each of four bud clusters were emasculated and bagged on Sarawak Creeping and four buds on each of six clusters on Changi No. 3. None of these flowers formed pods, showing that excision of the stamens was achieved without loss of pollen and chance selfing.

As this work was started after the height of the blooming season, the results reported in table 32 for artificial selfing of Changi No. 3 are slightly misleading because young pods were already growing on some of the clusters which had bloomed prior to the time the test was begun. The flower-bud clusters which were still sufficiently young to use in this preliminary trial had noticeably weaker stalks and fewer buds than those clusters that had formed earlier. These reductions

in flower number and size, together with the fact that the plants had already set some fruit, might explain the failure of the artificially selfed Changi No. 3 to mature any pods.

Seeds from pods resulting from crosses similar to those tabulated have been planted, germinated, and new seedlings have become fully established.

This preliminary work demonstrated that when varieties of *Derris elliptica* were reciprocally crossed, pods developed and matured. It seemed evident that flower buds should be removed from the clusters while they are still young, leaving only a few buds in each cluster to mature for pollination.

The studies of insecticidal plants were continued during the year under Rufus H. Moore, associate plant physiologist.

COFFEE INVESTIGATIONS

Cooperative work with University Experiment Station has continued successfully.

As outlined in previous annual reports, all the research on coffee at this experiment station is carried out in cooperation with the Experiment Station of the College of Agriculture of the University of Puerto Rico. The cooperation and experiments have progressed successfully during the year. Jaime Guiscafré-Arrillaga, coffee specialist of the University Experiment Station, has continued in active charge of the coffee investigations. Luis A. Gómez was appointed on January 1 as assistant to the coffee specialist.

Columnaris variety of Coffea arabica greatly outyielded the Puerto Rican variety.

The experiment comparing the yields of the Columnaris variety and the Santo Dominican or Puerto Rican coffee, both being varieties of *Coffea arabica*, was continued during the year. For the third successive year the Columnaris outyielded the Puerto Rican in yields of fresh berries and marketable coffee. The Puerto Rican coffee yielded 2,131 pounds of fresh berries per acre which gave 468 pounds of dried marketable coffee; the Columnaris yielded 8,762 pounds of fresh berries which gave 1,927 pounds of marketable coffee. It can be seen therefore that the Columnaris gave slightly more than four times as much coffee per acre as the Puerto Rican or Santo Dominican variety; the differences are highly significant. For convenience the yields for the past three successive years are summarized in table 33.

TABLE 33.—*Average yields per acre of fresh berries and dried marketable coffee for 3 successive years from an experimental grove comparing the Columnaris and Puerto Rican varieties of Arabian coffee, 1934–36* [1]

Variety	1934		1935		1936		Total	
	Fresh berries	Marketable coffee	Fresh berries	Marketable coffee	Fresh berries	Marketable coffee	Fresh berries	Marketable coffee
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Columnaris [2]	1,697	373	5,087	1,119	8,762	1,927	15,546	3,419
Puerto Rican [2]	1,691	372	2,805	617	2,131	468	6,627	1,457

[1] Experiment by McClelland, Guiscafré, Lee, Gómez.
[2] Replicated plats totaling 50 trees.

It can be seen that over the period of 3 years, the productive life of the coffee planting in this experiment to date, the Columnaris variety has given a total yield of 3,419 pounds of marketable coffee per acre as compared to 1,457 pounds yielded by the Santo Dominican or Puerto Rican variety; the increased yield of the Columnaris amounts to 135 percent.

In partial shading experiment coffee trees died in full sunlight.

The first quantitative shading experiment in which the shade was furnished artificially by lath covers was discontinued at the end of the year. It will be recalled from previous annual reports that in this experiment the trees in full sunlight greatly outyielded the trees with one-half and one-third the normal sunlight. Such trees in full sunlight, however, showed very poor vegetative vigor; during the year these trees died. The experiment has been a highly interesting one, and the conclusions to date would seem to be that shading is essential for coffee under Puerto Rican conditions, particularly when the plants are young, but that too much shading results in heavy vegetative

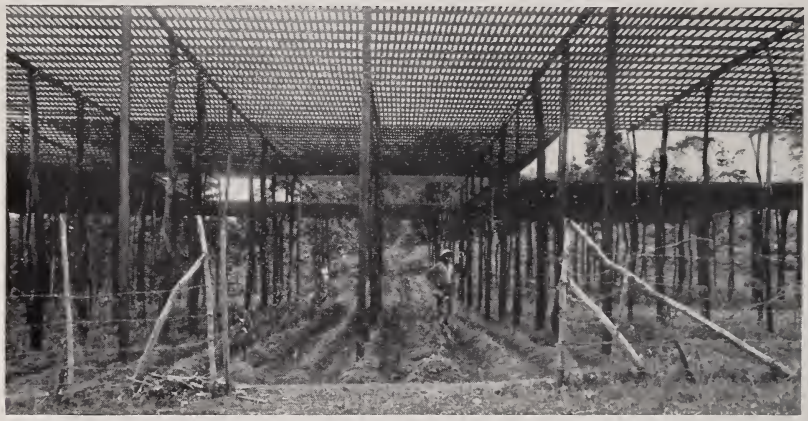

FIGURE 25.—Lay-out of shading experiment with Arabian coffee, testing growth and yields in full sunlight, two-thirds, one-half, and one-third sunlight; there are four replicated plats of each light treatment.

growth with diminished crop production. There is some slight evidence to indicate that insufficiency of nutrients is to some extent concerned with a greater requirement for shade.

New experiments are progressing.

The more extensive shading experiment begun last year, with four replicated plats of each treatment, has developed successfully to date. Figure 25 shows the lay-out. In this experiment the vegetative growth has been much the best in the heavily shaded plats with consistently less growth in the plats exposed to greater degrees of sunlight. No crop has been harvested from this experiment as yet.

The experiment, testing six species of legumes as shade trees for coffee, having six replicated plats for each species, has continued successfully. However, the coffee trees have not advanced as yet to the age at which berries are being borne and yields compared.

An area has been prepared and uniform shade trees planted for assembling in one planting the 38 coffee species, hybrids, and varieties which are growing at the experiment station.

SUGARCANE-VARIETY TRIALS

In sugarcane-variety trials the second-ratoon crop gave good yields.

The second-ratoon crop of sugarcane in a variety trial on irrigated lowland clay soil of the station was harvested during the period March 29 to April 5, 1937. The experiment was initiated in cooperation with the University of Puerto Rico and Central Eureka, Inc.

The yields from three crops harvested during this experiment are summarized in table 34.

TABLE 34.—*Summary of average yields of sugarcane per acre, percent sucrose in juice, and sugar per acre in a variety trial conducted on lowland clay soil on grounds of the Puerto Rico Experiment Station, Mayaguez, 1935–37*

Variety	Plant cane, 16-month crop [1]			First-ratoon, 12-month crop [2]			Second-ratoon, 12-month crop [3]			Average	
	Cane per acre	Sucrose in juice	Sugar per acre	Cane per acre	Sucrose in juice	Sugar per acre	Cane per acre	Sucrose in juice	Sugar per acre	Cane per acre	Sugar per acre
	Tons	*Percent*	*Tons*	*Tons*	*Percent*	*Tons*	*Tons*	*Percent*	*Tons*	*Tons*	*Tons*
P. O. J. 2878	61. 62	16. 74	8. 07	35. 30	14. 41	5. 31	40. 35	12. 94	5. 22	45. 76	6. 20
P. R. 803	61. 91	14. 73	7. 11	33. 32	12. 49	4. 15	28. 63	12. 31	3. 52	41. 29	4. 93
P. R. 807	67. 27	12. 88	6. 20	41. 67	13. 37	5. 61	35. 65	11. 76	4. 19	48. 20	5. 33
F. C. 916	58. 45	13. 08	5. 67	39. 35	13. 83	5. 46	32. 46	11. 86	3. 85	43. 42	4. 99
Mayaguez 63	80. 07	15. 55	9. 84	35. 88	13. 42	4. 79	41. 17	11. 73	4. 83	52. 37	6. 49
Mayaguez 23	53. 03	14. 57	6. 08	31. 45	13. 89	4. 36	28. 09	14. 00	3. 93	37. 52	4. 79

[1] Planted Nov. 1–8, 1933, harvested Mar. 3–8, 1935.
[2] Harvested Mar. 18, 1936.
[3] Harvested Mar. 29–Apr. 5, 1937.

Mayaguez 63 produced the highest average cane tonnage.

A study of the cane yields reveals the fact that Mayaguez 63 had the best record of all varieties, placing first in yield in the plant-cane crop, placing third in the first-ratoon crop, and first in the second-ratoon crop. P. R. 807 had the next best cane yield, placing first once, second once, and third once. It is of interest to note that the yield of Mayaguez 63 in the second-ratoon crop was greater than its yield in the first-ratoon crop; no explanation for this unusual increase in cane tonnage has been found.

Mayaguez 28 juice contained 14 percent of sucrose in second-ratoon crop.

The average percent of sucrose for all the juices decreased more or less uniformly in the successive crops. There were certain exceptions to this general rule, however, in that P. R. 807 and F. C. 916 showed higher percentages of sucrose in the first-ratoon crop than in either the plant-cane or second-ratoon crops. Mayaguez 28 juice contained 14 percent sucrose in the second-ratoon crop compared with 13.89 percent in the first-ratoon and 14.57 percent in the plant-cane crop.

P. O. J. 2878 outyielded all varieties in sugar per acre in second-ratoon crop.

The successive decline in yield of sugar per acre was more or less regular in all varieties with the exception of Mayaguez 63 which yielded a greater amount of sugar per acre in the second ratoons than in the first-ratoon crop. This result was brought on by increased average yield in cane rather than by a higher percentage of sucrose

in the juice. P. O. J. 2878 produced the highest yield of sugar per acre of all varieties in the second-ratoon crop.

Mayaguez 63 gave the best sugar yield for the three crops combined.

In summarizing the results of the three crops harvested in the variety trials, Mayaguez 63 gave a superior yield of cane per acre followed by P. R. 807, with P. O. J. 2878 third best. From the standpoint of average yield of sugar per acre for the three crops in this experiment Mayaguez 63 ranked first, P. O. J. 2878 second, and P. R. 807 third. The final results indicate that these three varieties may be expected to give better average yields of both cane and sugar on lowland clay soils in western Puerto Rico than Mayaguez 28, P. R. 803, or F. C. 916.

Statistical analysis of second-ratoon yields indicated superiority of P. O. J. 2878 and Mayaguez 63.

Yield records obtained in the plant-cane and first-ratoon crops and published previously showed statistically significant differences.

A. N. Watson, plant physiologist and biometrician of the station, analyzed the results of the second-ratoon crop and reported as follows:

> Mayaguez 63 and P. O. J. 2878 were significantly superior to F. C. 916, P. R. 803, and Mayaguez 28 in cane tonnage, but the difference in comparison with P. R. 807 was not statistically significant. As regards percent sucrose in the juices Mayaguez 28 was statistically superior to P. R. 803, F. C. 916, P. R. 807, and Mayaguez 63, but the difference when compared to P. O. J. 2878 was not significant.
>
> In yield of sugar per acre P. O. J. 2878 and Mayaguez 63 were statistically equal, but P. O. J. 2878 was significantly superior to P. R. 807, Mayaguez 28, F. C. 916, and P. R. 803. Mayaguez 63 was not significantly superior to P. R. 807 but was superior to Mayaguez 28, F. C. 916 and P. R. 803.

This experiment was laid out and planted by the experiment station of the University of Puerto Rico; the harvesting during the plant crop was supervised by R. L. Davis, agronomist, and the two ratoon crops by James H. Jensen, plant pathologist and physiologist, of this experiment station. Juice analyses and sugar calculations were by Hector E. Pabón, chemist of Central Eureka.

PLANT INTRODUCTIONS AND DISTRIBUTIONS

Many plants new to the island were introduced during the year.

Propagating materials of 300 species of plants new to the island were received during the year. These were classified as 7 timber species, 1 paint-oil species, 39 palms, 45 drug and insecticidal plants, 39 fruit and nut trees, 157 ornamentals, 4 bamboos, 3 aromatic-oil species, and 5 forage-crop plants. These species have been established in the experiment station nursery, from which, as they develop sufficiently, they will be transferred to permanent positions in the plant-introduction gardens.

Climatic and soils differences facilitate colonization of plant introductions.

Puerto Rico has a wide range of tropical environmental conditions, with altitudes varying from sea level to over 4,000 feet and with differences in rainfall in different localities ranging from averages of 20 to 200 inches annually. These elevations and rainfall variations, together with a considerable range of soil types, present opportunities to meet most tropical plant environmental requirements. The lands

of the station proper are at sea level, while those of the Las Mesas property of the station lie at an elevation of 1,000 feet. The soils in the lowlands are heavy compact clays which are soggy with moisture during the rainy season, while the soils of the Las Mesas property are loose, with rapid percolation and excellent drainage. When sufficient planting material of an introduced species has been available, plants have been set out on the Las Mesas property as well as in the plant-introduction gardens in the lowlands. If still more planting material was available, the species has been sent to the dry south coast for trial under such semiarid conditions. Thus, with sufficient propagating material, it has been possible to supply most of the desirable species from other tropical countries with an approach, at least, to comparable environmental conditions in this island.

Many plants and cuttings were distributed during the year.

As a result of the campaign of Governor Blanton Winship to beautify the island and thus augment its attraction as a tourist center, there have been increased requests for planting materials during the year. There were 68,020 plants propagated and distributed during the fiscal year, as compared with 34,641 distributed last year. The distribution of all classes of plants by months is shown in table 35.

TABLE 35.—*Economic and ornamental plants distributed during the year 1936–37*

	July	August	September	October	November	December	January	February	March	April	May	June	Total
Plants:	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Avocado varieties								6	3	2	4		15
Bamboo species	152	179	7	17	41			4	12	22	1		435
Buginvillaea varieties	142	904	67	425	187	68	89	117	172	186	17	268	2, 642
Hibiscus varieties	546	1, 218	1, 411	957	2, 038	2, 096	4, 932	4, 022	2, 016	5, 795	15, 960	817	41, 808
Mango varieties	126	72	22		40		20	1		10	58	10	359
Miscellaneous economic plants	101	58	89	9	2	1	22	20	3	7	25	40	377
Miscellaneous fruit plants		43	594	26	245	158	10	20	261	54	51	154	1, 616
Miscellaneous ornamental plants	973	592	742	972	1, 299	616	894	768	1, 144	1, 028	1, 157	1, 439	11, 624
Ornamental vines	18	40	25	77	218	16	18		278	78	181	217	1, 166
Palm species	50	224	149	328	878	171	77	421	1, 258	606	348	224	4, 734
Plantain suckers	749	1, 445											2, 194
Timber plants				550	2	8	70	71	3				704
Waterlily plants			10	24	22			16	43	32	7	26	180
Wax-flower plants [1]		20	20	9	3	6	30	5	9	2	12	4	120
Citrus plants		11	23		6			2			4		46
Total	2, 857	4, 806	3, 159	3, 394	4, 981	3, 140	6, 162	5, 473	5, 202	7, 822	17, 825	3, 199	68, 020
Seeds:	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Coffee varieties			1	10	10								21
Miscellaneous plants				6			139	38					183
Palm species			1						½				1½
Grass species								2					2
Sweet corn			8	500			43	19		67	132		769
Total			10	516	10		182	59	½	67	132		976½

[1] *Phaeomeria speciosa.*

Many of the ornamental plants were requested by schools for the beautification of their grounds. Other government agencies, both Federal and insular, have also received plants for their grounds and buildings. Roadside plantings by district engineers of the insular government also required large quantities of ornamental trees.

Several new ornamentals found by the station's plant-introduction studies to merit extensive planting were propagated and distributed.

In all of these distributions of ornamentals, leguminous, nitrogen-fixing plants are now being favored because of the general impoverishment of the island soils, resulting from erosion, and the necessity to utilize every possibility for the gradual rehabilitation of the soils.

Five paint and varnish oil-producing Aleurites have been introduced.

The tung oil of commerce is produced mostly in China from nuts borne by the tree *Aleurites fordii*, and it is this species which has been planted extensively in Florida and Mississippi in recent years. This experiment station introduced *A. fordii* into Puerto Rico in 1910, but it did not thrive in the Mayaguez environment and died out; it seems to be a species that is not particularly tropical but adapted to the environmental conditions of the cooler subtropics.

The candlenut of Malaysia, *Aleurites moluccana*, is a related species that is distributed throughout Puerto Rico, apparently spontaneous after cultivation. The kernel of the extremely hard-walled seed of this species yields an oil useful in paint and linoleum manufacture which, however, is comparatively slow drying and this species is, therefore, not so useful as *A. fordii*. No commercial culture of the candlenut is carried on in Puerto Rico.

Another member of the genus, *Aleurites trisperma* of the Philippine Islands, was introduced by the station about 1909 and has shown itself well adapted to this environment. The original tree was destroyed by a hurricane in 1928, but five mature trees are now growing luxuriantly on a heavy clay soil at the station and now produce abundant crops of soft-shelled seeds. The oil expressed from the large kernels is a valuable paint oil, although it is not considered so useful as the oil from *A. fordii*.

Aleurites cordata, of Japan, was introduced into Puerto Rico this year. Studies by the Bureau of Chemistry and Soils have shown the oil of this species to be of quality sufficiently like the tung oil of *A. fordii* to indicate that it will have considerable industrial value. Young trees of *A. cordata* 4 months old have good vigor, and thus far show this environment to be suitable for their development.

Aleurites montana of southeastern China was introduced several years ago, and one tree has persisted. It, however, is not as vigorous in this environment as are *A. trisperma* and *A. moluccana*.

An area of approximately 1½ acres was planted with seedlings of *A. trisperma* from seed produced by the station trees. This season's seed crop was used for plants to give this species more extensive trial through plantings at other locations in the island.

Centipede grass has produced good lawns under Mayaguez conditions.

During the year comparisons of lawn grasses have continued which included the following species: Java grass, *Polytrias amaura;* Bahia grass, *Paspalum notatum;* centipede grass, *Eremochloa ophiuroides;* velvet grass, *Zoysia tenuifolia;* Manila grass, *Z. matrella;* Korean lawngrass, *Z. japonica;* carpet grass, *Axonopus compressus;* sour grass, known locally as grama, *Paspalum conjugatum;* and St. Augustine grass, *Stenotaphrum secundatum*.

In these trials centipede grass has seemed to date to be most desirable for lawns under Mayaguez conditions. Velvet grass developed into a fine-textured, dense turf, but its growth has been slow. Bahia

grass, St. Augustine grass, carpet grass, and grama are all broad-leaved and are good soil covers but make lawns of coarse appearance. Manila grass and Java grass both produce seeds abundantly and form fine lawns, but in the wet conditions of Mayaguez on heavy clay soils they are susceptible to disease attacks. Korean lawn grass has grown slowly.

The indigenous legume, *Meibomia triflora*, under observation for its usefulness for lawns, was seriously attacked by webworms. A second lawn legume, *Alysicarpus vaginalis*, continued vigorous growth. These legumes have been useful in lawn mixtures, but it appears that neither should be grown as a pure-stand lawn species.

Two rattan-producing palm species have been introduced.

The commercially important rattan canes imported into the United States for use in the manufacture of furniture are the stems of several climbing palm species. These rattan palms are mostly indigenous to southeastern Asia and the East Indies and are found in tropical America only as a few individual specimens in botanic gardens. These palms, which normally occur in forests, climb about over shrubs and trees and reach lengths of 80 to 120 feet.

Daemonorops and *Calamus* are the outstanding palm genera, the stems of which yield rattan canes. During the year seeds of the commercial species *D. mollis* were obtained from the Bureau of Forestry of the Philippine Islands. Forty vigorous plants of this species are growing from that seed. A second lot of seeds of *D. mollis* received from the College of Agriculture in the Philippines has germinated well. Five plants of *C. viminalis* from seed received from the Botanic Garden, Calcutta, India, are also growing vigorously. Both of these species are spiny and will be of possible commercial value when grown on wooded, steep hillsides not suitable for cultivated crops.

Trials showed some varieties of mangoes could be successfully desiccated.

Because of the presence of the West Indian fruitfly, *Anastrepha* sp. probably *A. mombinpraeoptans* Seín, according to the Bureau of Entomology and Plant Quarantine, mango fruits to be marketed on the mainland must be processed in such a way as to kill all insect larvae present. Sulphuring and desiccation of the fruit is one means of killing such larvae; preliminary observations were made to determine what varieties of mango fruits could be given such form of processing. In the trials a desirable dried product was obtained from the prolific full-flavored and large-fruited Sandersha variety. Varieties such as Cambodiana, Jamshedi, Mulgoba, and Bulbulchasm, which are considered good as fresh fruits, lost much of their flavor when desiccated. Varieties having considerable fiber in the flesh were of little or no value for desiccation.

Through apogamic means many mango seedlings produce fruit of the same character as those of the female parent; however, some seedlings are the result of fertilization of the flowers and it is through this last type of seedlings that new varieties have originated. Under the conditions prevailing in the station groves, possibilities for the origination of desirable new varieties are favorable. Twelve hundred seedlings of known female parentage from these groves have been

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grown in nurseries and are now ready for transplanting into proving groves.

Three varieties were added to the already extensive collection of mango varieties of the station. The variety Colombo Kidney was obtained from a seedling tree introduced into Puerto Rico by Miss Mary Leitch direct from India about the year 1912; a second variety, the Pere Luis, was introduced in the form of seeds from the French island of St. Martin in the West Indies; the Brooks from Florida was obtained as scions from the Bureau of Plant Industry.

Growth response of quinine species to Puerto Rican environment varies.

In the annual report of last year mention was made of some of the difficulties encountered in the establishment of quinine, *Cinchona*, plants in Puerto Rico. During the year under review a wide diversity of growth has been observed in quinine trees introduced in 1933 and planted at the Maricao Insular Forest. Some of the plants have reached a height of 6 to 7 feet, while others are only slightly taller than they were at the time of setting out. Plants of *Cinchona ledgeriana* do not seem to make the thrifty growth shown by the other species of the genus which have been planted.

Quinine plants have serious insect enemies.

In the 1935 plantings *Cinchona officinalis* grew rapidly. Plants of all species, however, were attacked by three different species of scale insects of which the most common was the green scale, *Coccus viridis* (Green), while the white peach scale, *Aulacaspis pentagona* (Targ.), was present in abundance and the brown hemispherical scale, *Saissetia hemisphaerica* (Targ.), present to a lesser extent. *C. ledgeriana* and *C. succirubra* seemed to be particularly susceptible to the green scale, while *C. officinalis* was comparatively free of infestation in the same environment. The *Coccus viridis* was attacked by entomogenous fungi but apparently not until a large population was built up and serious damage already caused to the young plants. Apparently some of the earlier difficulties, particularly with *C. ledgeriana*, were caused by those scale insects.

All of the original trees of the 1935 planting at Doña Juana were transferred to Maricao during the year. The results at Doña Juana were discouraging, whereas the plants at Maricao now show somewhat better thrift.

Experience has increased knowledge of the requirements of Cinchona plants.

Mention was made last year of the introduction of approximately 1,000 *Cinchona* trees; the species received were *Cinchona calisaya*, *C. ledgeriana*, *C. ledgeriana*×*officinalis*, *C. succirubra*, *C. ledgeriana*×*succirubra*, *C. officinalis*, and two unknown species listed by their introduction numbers. These were received as small seedling trees from the Division of Plant Exploration and Introduction of the Bureau of Plant Industry and planted in three localities at different elevations in the island. Some increased knowledge of the requirements of *Cinchona* has been derived through experience, and the most recent shipments have better prospects for favorable growth than those made in previous years.

Newly introduced Cinchona plants seem thrifty.

During the year under review 2,600 additional plants were received from the Bureau of Plant Industry. The species represented in these introductions were *Cinchona ledgeriana, C. succirubra,* and four undetermined *Cinchona* species, the seed of one of which was obtained from Bolivia. None of these more recent introductions duplicated the introduction numbers of 1935. The foregoing seedlings are being maintained in nurseries until they attain the proper size for field planting. Nurseries are being maintained at Camp Doña Juana in the Toro Negro unit of the Caribbean National Forest at an elevation of 3,000 feet, at Castañer at an elevation of 2,000 feet, and at Las Mesas at an elevation of 1,000 feet. The plants in these nurseries seem unusually thrifty; those at the elevation of 1,000 feet seem to be doing as well as those at higher elevations at this latitude.

Several introductions have been expanded to experimental plantings.

In the 1935 annual report of the station mention was made of the apparent value of the palm chestnut, *Guilielma utilis,* a native of Honduras and Guatemala, where it is known as the Pejibaye palm. A considerable quantity of seeds of this species was purchased through the cooperation of the Plant Introduction Gardens of the Panama Canal Zone and were germinated here. From the resulting seedlings approximately one-half acre has been planted to this species on a sloping field of possibly 45-percent grade in the lowlands of the station proper. Another half acre has been planted to the same palm on a forested hillside of similar slope at Las Mesas. Both plantings now seem to be well established; growth on the porous, well drained, but less fertile soils at Las Mesas to date has seemed to be better than in the heavier lowland soils. This species has the advantage that it can be grown on steep hillsides without terracing and to some extent will aid in checking soil erosion.

A considerable extension of the wax flower, *Phaeomeria speciosa,* also described in the 1935 report, has been made. An experimental shipment of flowers of this species was made to Washington during the year. The flowers were picked as buds, placed in shipping boxes, and forwarded at temperatures of from 34° to 36° F. On arrival in Washington they were in good turgid condition, but the buds had not opened and they had developed a slightly disagreeable odor. Observations of these cut flowers have since shown that the opening of the flower is halted by cutting. When shipping methods are developed, it is expected that these exotic flowers will have income possibilities for a small acreage in the moist parts of the island; the plants of this species have the advantage of checking soil erosion.

Introduction gardens have been extended.

Because of the steady increase in the number of plant introductions, considerable extension has been necessary in the garden devoted to such new plants. The hillsides of a valley lying immediately to the rear of the office and laboratory building of the station have been gradually developed as terraces during the past 5 years. Such terraces not only check soil erosion but lend themselves to accurate charting of the different species represented. Some of the newly introduced grasses and legumes of possible value as lawns and soil covers have been planted on these terraces in addition to the shrub

and tree introductions. These plantings are gradually giving a more gardenlike appearance to the terraces, at the same time extending the areas of these ground covers and making them available for distribution as they may seem desirable.

Claud L. Horn, associate horticulturist, has continued in charge of plant introductions and distributions during the year.

PLANT-DISEASE INVESTIGATIONS

STUDIES OF PAPAYA BUNCHY TOP

Bunchy top is a new disease of papaya in Puerto Rico.

Within recent years a new disease of papaya, *Carica papaya*, called bunchy top by Cook [3], has appeared in Puerto Rico. It is possible that this disease is present in other countries, but no definite record of its occurrence elsewhere is known to us.

The disease stunts plants and renders the fruits tasteless.

Bunchy top is an economically important disease to papaya growers in Puerto Rico. The disease not only seriously stunts plants and thereby curtails production but also tends to give such few fruits as are produced on diseased plants an insipid or sometimes tasteless quality. A high proportion of plants may become diseased; as many as two-thirds of the plants in some plantings were found to be diseased.

Information regarding bunchy top of papaya is meager.

The cause of papaya bunchy top is not known. Cook believed the disease to be caused by a plant virus; however, no experimental transmission evidence has been presented to indicate the validity of this assumption. During the past year attempts were made to learn more regarding the symptoms of the disease, to determine its cause, to learn the means of transmission if it proved to be an infectious disease, and to find means of control.

Cessation of growth at tip produces characteristic symptom.

One of the earliest evidences of the diseased condition is the appearance of abnormally yellow young leaves. This symptom is soon followed by a change in the angle of divergence assumed by the uppermost petioles. Instead of being borne almost vertically, as is the case in healthy plants, these petioles extend almost horizontally sometimes nearly at right angles to the main stem of the plant. Petioles of young leaves are shortened to as much as a fourth or a half of their normal length. The internodes, while short in healthy plants, are even shorter in diseased plants. Petioles of healthy young leaves are usually colored a light green; in diseased plants the petioles are slightly lighter or more yellowish in color and in addition frequently contain small dark-green areas, giving the entire petiole a mottled appearance. Usually this mottling appears more concentrated in the basal portions of the petioles.

In contrast to the upper leaves which become yellow in a diseased plant, leaves lower on the stem, which were already full grown at the inception of the symptoms, retain their green color and show no symptoms of the disease.

[3] Cook, Melville T. NEW VIRUS DISEASES OF PLANTS IN PORTO RICO. Jour. Dept. Agr. Porto Rico 15: 193-195, illus. 1931.

Diseased leaves are more rigid than healthy leaves.

In addition to the color change and the angle at which the petioles are borne, diseased leaves become stiffened and somewhat rigid instead of being supple as in the normal plant. This symptom makes it possible to distinguish recently diseased plants at some distance because the leaves, instead of hanging naturally with most of the points of the serrations inclined downward, have these points extending upward in a characteristic manner.

Flowers show marked symptoms of the disease.

Papaya plants that become diseased in their early stages of growth seldom produce flowers. Plants that do not become diseased until they reach the flowering stage produce dwarfed flowers. In the case of diseased female plants, the flowers do not open but fall off when one-fourth to one-half developed. Diseased male plants produce shrunken and distorted flowers that drop prematurely.

Diseased plants produce few or no fruits.

Bunchy top may affect papaya fruits in several ways. Fruits that are nearly full-grown when symptoms of the disease first appear often become tasteless or develop an insipid flavor. Fruits that are undeveloped when symptoms first appear may grow unevenly and become misshapen; they may be dwarfed or stunted or they may soon fall off. In only a few instances was it noted that diseased plants produced fruits that were comparable with those produced by healthy plants, and in all such instances symptoms of the disease appeared after fruits were nearly fully developed.

Diseased plants contain less latex than healthy plants.

Papaya plants are latex-producing, and wounding of the leaves, stems, or green fruits of healthy plants is immediately followed by a flow of white, milky, sticky fluid at the point of injury. It was noted that recently diseased plants exuded markedly less latex at the point of injury, and plants that had been diseased for some time produced practically no latex.

New shoots frequently arise on stems of diseased plants.

Following the appearance of disease symptoms at the tip of the stem, and the subsequent stunting of that portion of the plant, new shoots usually arise from some of the axillary buds farther down the stem. These young shoots are usually healthy. Sometimes they begin to grow and after a slight development show symptoms of the disease. It has frequently been noted that the symptoms of the disease progress downward from the tip of the plant; that is, as a rule, the shoots coming from the lower axillary buds are the last to show symptoms of the disease. Frequently the shoots coming from lower axillary buds never show symptoms of bunchy top, but continue to grow and appear healthy in spite of the diseased condition of the top of the plant.

Some diseased plants were cured by cutting off diseased tops.

A series of experiments was undertaken in an effort to determine if diseased portions of a plant could be removed in such a way that shoots arising from the lower buds would continue to grow and remain healthy.

Ten plants that were about 16 months old and all of which had been diseased for more than 3 months were cut back in such a way that the upper part of the stem of each plant showing disease symptoms was removed. The cut surfaces of the stem were coated with paraffin to prevent excessive loss of water through evaporation. Within several weeks after cutting, new growth took place from the axillary buds of the lower leaves. In 9 of the 10 plants all new shoots were healthy. In the one case the new shoots were diseased and showed typical symptoms of bunchy top. About 3 months after cutting back, shoots on four of the cut-back plants showed symptoms of the disease. The other five plants continued to appear healthy. At 5 months 2 of the 10 formerly diseased plants to all appearances were still healthy. Three additional plants had only one or two diseased shoots each.

Trees blown down also may produce healthy shoots.

In this same connection it was observed that diseased trees as well as healthy trees are sometimes blown down by strong winds. Usually such recumbent trees cease growing at the apical end of the stem, and new growth occurs at one or several of the axillary buds along the axis of the stem. In a number of instances new growth has been seen to arise from diseased plants, and in almost every such case the new growth was healthy in appearance, and in several instances the new shoots grew up healthy and produced fruit.

Natural recovery was observed.

In addition to the production of healthy new growth which was observed under the conditions described, it was also observed that recovery may take place without unnatural manipulations. In a fairly large number of cases where it had been definitely known that the plants were diseased recovery occurred. Such cases were usually observed to occur during the dry season—that is, during the period of the year when few rains occur. Prolonged dry weather brings about a practical cessation of new growth. The instances of recovery which have been definitely observed have all occurred with the advent of new growth following a prolonged drought. This recovery phenomenon was observed in more than 25 plants. These observations were made on experimental plantings as well as in several small home plantings.

No micro-organism has been observed in diseased tissue.

In studies on the cause of bunchy top of papaya, numerous unsuccessful attempts were made by microscopic examination of free-hand stained and unstained sections to locate bacteria, fungi, or protozoan organisms in diseased stems, petioles, or leaf parts. Attempts to isolate micro-organisms from diseased tissue also were fruitless, although a number of different culture media were used.

All attempts to transmit the disease mechanically failed.

Numerous experiments were conducted in an attempt to transmit papaya bunchy top by mechanical methods but without success. Inoculations were made by rubbing the juices of diseased plants on leaves of healthy plants. In several experiments inoculations were made with the aid of carborundum, a material known to increase the efficacy of inoculation technique in the case of transference of certain virus diseases. Attempts were made to inoculate healthy plants by injecting diseased juice with a hypodermic syringe; also to transmit

the disease by the pin-puncture method wherein a drop of juice from the diseased plant was placed in the axil of the leaf and a small insect pin used to puncture the tissue immediately beneath the drop of diseased juice by pushing the needle through this drop.

Disease was not transmitted by budding.

Numerous attempts were made to transmit bunchy top by budding. Buds from diseased plants were grafted on healthy plants. In most cases the buds did not survive. Grafting was performed with paraffin, with grafting wax, and without either of these materials. It was observed that healthy buds grafted onto a healthy plant survived much more frequently than diseased buds. This is undoubtedly due to the decreased vigor of diseased buds. In no instance under controlled conditions was the disease transmitted by means of budding.

Attempts were made to transmit disease by approach grafting.

A large number of attempts were made to transmit papaya bunchy top by means of approach grafting or inarching. Healthy plants were grown in large clay pots, and when they had reached a height of 24 to 40 inches they were removed to the field and placed adjacent to shoots of the plant to which they were to be grafted. Approach grafts were made with both diseased and healthy shoots. During the preliminary experiments a number of grafted plants became diseased. However, since all plants tested were grown in the field without protection from insects, there was still the possibility that the transmissions obtained were not the result of grafts but rather new cases of the disease.

Experiments indicated that the occurrence of bunchy top depends upon insect visitation.

In an attempt to determine whether the transmissions occurring with grafted plants were the result of grafting or of some other means, the following experiment was carried out: Thirty healthy young papaya plants growing in 6-inch pots were divided into 3 similar groups of 10 plants each. The plants of 1 group were grafted by the approach-grafting method onto 10 diseased shoots in the field. The plants of the second group were distributed in the field in such a way that each plant was placed about 1 foot away from a grafted plant. Thus the plants of the second group were brought into similar situations as to the plants of the first group, but they were not grafted to diseased plants, nor were they permitted to touch the diseased plants. The 10 plants of the third group were placed in an insect-proof enclosure within 20 yards of the location of the grafted and nongrafted plants. At the end of 3 weeks, 7 of the 10 grafted plants showed symptoms of bunchy top; 5 of the 10 plants placed near diseased plants showed symptoms of the disease. None of the plants in the screened enclosure showed disease symptoms, although they had been treated in all respects exactly the same, aside from being placed in an insect-proof enclosure. At the end of 4 weeks all grafted plants were diseased; 8 of the plants placed near grafted plants were diseased, and none of the screened plants were diseased.

Plants protected from insects never became diseased.

At different times during the course of these studies, groups of plants have been divided, part being planted in the field and the remainder potted in large clay pots and held in the greenhouse. In

each instance some of the plants set out in the field became diseased whereas in no instance have greenhouse plants become diseased, even though some were held for periods of more than 9 months. Furthermore, no plants growing in the insect-proof greenhouse ever became diseased although the greenhouse is located contiguous to the field where many diseased plants were grown.

It was concluded from these experiments that the occurrence of bunchy top depends upon insect visitation.

No successful transmissions were obtained with insects.

Careful observations were made on insects infesting the plants. More than 40 attempts were made to transmit this disease by transferring insects that were found feeding on diseased plants to healthy plants. Among the insects found on papaya and tested for transmission were the lacewing bug *Corythucha gossypii* (F.), the stinkbug *Nezara viridula* (L.), and two species of leafhoppers, *Agalliopsis pepino* (De L. and Wolc.) and *Nesosteles incisus* (Mats.). While the trials with insects were not sufficiently extensive to be conclusive, in no instance were typical symptoms produced.

All varieties tested were susceptible to papaya bunchy top.

At the beginning of these studies it was hoped that papaya varieties resistant to bunchy top could be found, which would provide a simple and practicable control of the disease. During the past year papaya seeds from a number of different sources were planted and the seedlings were set out in a field on the grounds of the experiment station. These plantings permitted observations on the response of the varieties to the disease under field conditions.

Variation in ages and in number of plants did not permit an exact comparison among the varieties. However, of the six lots of seed thus far tested, plants of each lot became diseased. In these tests no completely resistant variety was found; one variety showed such high susceptibility that it would be inadvisable to attempt any commercial plantings of it.

Table 36 shows the dates of planting, numbers of plants set out, numbers of plants diseased on February 1, and the locality from which each lot of seed was originally obtained.

TABLE 36.—*Summary of natural infection obtained in papaya variety plantings under field conditions on the experiment station grounds from records of diseased plants made Feb. 1, 1937* [1]

Variety	Date of planting	Plants	Plants diseased	Localities from which seed was originally obtained
		Number	*Number*	
Puerto Rican A [2]	Nov. 15, 1935	43	35	Isabela, P. R.
Puerto Rican B [2]	Nov. 20, 1935	4	3	Hormigueros, P. R.
Puerto Rican C [2]	May 15, 1936	26	11	Bayamón, P. R.
Solo (Accession No. 2678) [3]	July 1, 1936	9	6	Hawaiian Islands.
Redflesh (Accession No. 2741) [3]	Aug. 10, 1936	12	3	Do.
Puerto Rican D [2]	Sept. 1, 1936	41	7	Cataño, P. R.

[1] Records by Jensen.
[2] Seed from plants of which exact history was unknown.
[3] Reference to seed or plant introduction accession number of Puerto Rico Experiment Station.

Summary of bunchy top investigations.

To summarize the results of studies on papaya bunchy top, the disease severely stunts affected plants and produces dwarfed leaves, causes shortened internodes, premature fall of flowers, and tasteless

fruits. Although many attempts were made to transmit bunchy top by juice inoculation, rubbing with juice from diseased plants, budding and grafting, in no case was the disease transferred under controlled conditions, nor did the disease occur on plants from which insects were excluded, although plants from the same lots became diseased when exposed to the feeding of insects. It was concluded that the occurrence of bunchy top depends upon insect visitation. All varieties tested were susceptible to the disease.

One of the unusual features of the behavior of bunchy top is that apparently diseased plants sometimes recover and that they may frequently be cured by cutting away the diseased top of the plant.

STUDIES OF SUGARCANE CHLOROSIS

Areas along the south coast produce chlorotic sugarcane year after year.

Certain areas of land along the south coast of Puerto Rico have for a number of years produced sugarcane plants exhibiting a leaf chlorosis. Areas producing diseased plants vary in size from a fraction of an acre to many acres in extent. Previous work by chemists of the experiment station [4] indicated that the cause of the chlorosis was a deficiency of available iron, with an excess of lime possibly acting as a contributing cause.

Symptoms resemble those attributed to manganese or iron deficiency diseases in Hawaii.

The leaf symptoms produced by diseased plants consist of yellowish green, yellow, or yellowish white interveinal areas lying between veinal areas of almost normal green color. In severe cases leaves become almost completely white in color and plants die. These symptoms of the diseased cane strikingly resemble symptoms which have been described for plants affected with manganese or iron deficiencies.

Ferrous sulphate solution brushed on diseased leaves produced recovery of green color.

In an early series of experiments chlorotic leaves of diseased plants were treated with the following solutions: Ferrous sulphate, manganese sulphate, copper sulphate, and boric acid. These solutions were applied with separate camel's-hair brushes and only one solution was applied to any given cane stalk. At the end of 3 weeks leaf areas brushed with ferrous sulphate had turned green, whereas leaf areas brushed with any one of the other solutions showed no response. These experiments, together with similar treatments applied as aqueous spray solutions, were repeated a number of times in different locations on different varieties of cane, and in each case iron sulphate applied to the leaves was followed by recovery of green color, whereas following other treatments no response occurred.

Field control experiments of the disease were attempted.

In Hawaii successful control methods have been worked out with Pahala blight, a disease caused by manganese deficiency. In the hope that similar field control methods might be found successful in Puerto Rico, three types of experiments were undertaken: (1) A dusting experiment with sulphates of iron and manganese, (2) a sulphur mangan-

[4] GILE, P. L., and CARRERO, J. O. CAUSE OF LIME-INDUCED CHLOROSIS AND THE AVAILABILITY OF IRON IN THE SOIL. Jour. Agr. Research 20: 33–62, illus. 1920.

ese-sulphate application to the soil, and (3) a sulphur-quantity experiment as soil applications.

Each experiment consisted of 24 plats of one-tenth acre in size, each treatment and control being repeated six times in randomized plats. The lay-out of one of the experiments of this type is shown in figure 26. Table 37 shows the distribution, cane varieties, and age of cane used in the various experiments. All soil treatments were made during the early part of the growing season when the cane plants

D6	B5	C4	B3	C2	A1
C6	A5	D4	A3	D2	B1
B6	D5	B4	C3	A2	C1
A6	C5	A4	D3	B2	D1

SYMBOL	No. OF PLATS	POUNDS OF SULPHUR		
		PER ACRE	PER PLAT	PER ROW
A	6	1,000	101.60	8.47
B	6	2,000	203.20	16.94
C	6	4,000	406.40	33.88
D	6	NONE	NONE	NONE

FIGURE 26.—Lay-out of one of the amounts-of-sulphur experiments on chlorotic sugarcane, conducted cooperatively by Luce & Co., Cortada Division, and the experiment station.

were 24 to 36 inches high. Some of the dust applications were made when the cane was slightly older.

TABLE 37.—*General location and varieties of sugarcane used in field experiments on the control of chlorotic sugarcane*

Experiment No.	Location	Title of experiment	Variety	Date of treatment
1	Santa Rita	Amount-of-sulphur	P. O. J. 2878	May 13, 1936.
2	do	do	Mayaguez 28	May 14, 1936.
3	do	Sulphur-manganese sulphate	P. O. J. 2878	June 2–3, 1936.
4	do	Dusting experiment	do	June 3, 1936.
5	do	Sulphur-manganese sulphate	Mayaguez 28	June 3–4, 1936.
6	Mercedita	do	Co. 281	June 10, 1936.
7	Cortada	Amount-of-sulphur	B. H. 10 (12)	June 23, 1936.
8	do	Sulphur-manganese sulphate	do	Do.
9	Santa Rita	Dusting experiment	Mayaguez 28	Sept. 1, 1936.
10	Cortada	do	B. H. 10 (12)	July 21, 1936.

No differences in yield were obtained in dusting experiments.

In the dusting experiments it was hoped that the dust might accumulate in the upper portion of the leaf whorl and that the water from dew or rain frequently found at this point would dissolve the material. Thus through growth and elongation it was hoped the leaves would be bathed in a solution containing the material to be tested. It was found, however, that winds prevented the accumulation of dust applications in the leaf whorls and also the field areas in which the dust was applied were notably arid, and little or no material went into solution. Replicated plats were dusted with the following materials: Iron sulphate, manganese sulphate, and sulphur. Control plats received no treatment. No significant differences in yield were obtained with any of the dust treatments, and no recovery of green leaf color was observed in any of the treated plats.

No increase in yield was obtained with manganese sulphate.

In a second series of experiments replicated plats were treated as follows: Sulphur applied at rate of 1,000 pounds per acre, manganese sulphate applied at rate of 200 pounds per acre, both sulphur and manganese sulphate applied. Control plats received no treatment.

No improvement in color of diseased cane was noted during the growing season, and no significant differences in yields of cane were found to occur in any of the treatments.

Attempts were made to decrease soil alkalinity by application of sulphur.

In the third series of experiments, attempts were made to decrease the alkalinity of the affected soil through applications of sulphur. Experimental evidence in general indicates that iron is more available to the plant under neutral or acid than alkaline conditions. It has been found in Hawaii that sugarcane plants affected with chlorosis due to manganese deficiency and iron deficiency frequently respond favorably if the reaction of the soil can be made more acid.

It is reported that sulphur has been used successfully in decreasing the alkalinity of certain soils.

Experimental areas were treated with none to 4,000 pounds of sulphur per acre.

A series of experiments was set up in which replicated plats were treated with 1,000, 2,000, and 4,000 pounds of sulphur per acre for comparison with untreated plats. Each treatment was carried out with six replications, each of which consisted of a plat of sugarcane one-tenth acre in extent except in one experiment where all plats were 0.1016 acre in extent.

Experiments conducted in three different locations.

An experiment similar in design to the one shown in detail in figure 26 was set up on three different locations, each of which was planted to a different variety of cane. One experiment was conducted on land producing chlorotic sugarcane planted to the variety B. H. 10 (12), another on land planted to the variety P. O. J. 2878, and a third to the variety Mayaguez 28.

Application of sulphur produced no decrease in alkalinity during one year.

At the time the treatments were applied, soil samples taken from each plat were tested for hydrogen-ion concentration by J. O. Carrero, assistant chemist of the experiment station. Similar determinations were made several times during the following year. The results clearly indicated that no sulphur treatment, even 4,000 pounds per acre, produced any decrease in soil alkalinity during the first year. The plats are being continued under observation, and possibly some definite effects of the sulphur may become noticeable later.

No significant differences in yield of cane were obtained by applications of sulphur.

The yield data obtained in these three experiments were analyzed statistically by A. N. Watson, biometrician and plant physiologist of the experiment station, who found that the differences in yield of cane obtained by the application of sulphur up to 4,000 pounds per acre were not statistically significant in any one of the three locations or with any one of the three sugarcane varieties tested.

Summary of experiments on the control of sugarcane chlorosis.

It was confirmed in these studies that the cause of sugarcane chlorosis on the south coast of Puerto Rico is due to a deficiency of iron. No measurable increases in yield of cane or noticeable improvement in color of leaves was obtained by dusting with iron sulphate, manganese sulphate, or sulphur. No significant increases in yield of cane were obtained by the application of 200 pounds of manganese sulphate per acre or by the application of up to 4,000 pounds of sulphur per acre.

CONTROL OF CHLOROSIS IN GRAPEFRUIT

A chlorotic disease on citrus lessens production.

Citrus trees along parts of the north coast of Puerto Rico have been affected in recent years with a chlorotic leaf disease. The diseased condition has been noticed especially on grapefruit, but also on lime and orange trees. In early stages of the disease, an irregular yellow spotting appears in the areas between the leaf veins. In seriously affected cases the leaves are small and much narrower than usual, some dying-back occurs in the twigs, and multiple buds appear. A similar disease in California and Florida is known as mottle-leaf or frenching, and there is evidence to indicate that it is noninfectious and probably due to abnormal nutrition. Affected trees produce small and few fruits or none at all.

Zinc sulphate sprays produced quick recovery.

In preliminary experiments undertaken in an attempt to learn the cause of the disease, aqueous solutions of zinc, ferrous copper, and manganese sulphates were sprayed on the trees. Three weeks after the diseased trees had been sprayed, it was noticed that those treated with zinc sulphate produced new growths of light-green leaves showing no signs of chlorosis. The trees sprayed with the copper sulphate soon shed all the leaves that were chlorotic. Trees sprayed with the other two substances showed no changes at the end of 3 weeks after treatment.

Control of mottle-leaf in grapefruit was obtained in two large-scale experiments.

Two large-scale grove experiments were started in an attempt to determine the optimum number of spray applications to be made per year. Each experiment consisted of six replicated plats of each treatment. The treatments consisted of one, two, and three applications of zinc sulphate per year, while randomized control plats received no treatment.

One spray application produced complete recovery in moderately affected trees.

On February 25 and 26 all plats except the controls were given an application of spray composed of 7 pounds of zinc sulphate per 100 gallons of water. It was found that an average of 40 to 50 trees could be sprayed with each 100 gallons of solution. About 3 weeks after this first spraying signs of improvement were noted on all treated trees. Trees that showed only moderate chlorosis previously, in general completely recovered. Trees more seriously affected showed marked responses in the production of new healthy appearing leaves. Scattered branches that had few or no leaves at the time of spraying showed least response. It is believed likely that the lack of leaves at the time of spraying curtailed the amount of zinc sulphate received by those particular branches and hence caused the lack of response obtained.

Unsprayed trees continued to show symptoms equal to or more severe than those noted at the time of spraying. New leaves were produced, but these showed marked chlorotic symptoms. The sprayings have been continued and harvest results will be obtained for comparison of yields from the different treatments.

It was concluded that citrus chlorosis in Puerto Rico is similar to or identical with frenching of citrus in Florida or mottle-leaf in California.

PLANT QUARANTINE SERVICE

Quarantine house has been used to full capacity.

The plant quarantine house constructed a year ago on the grounds of the experiment station has been filled to capacity ever since its completion. Both Federal plant quarantine and insular plant quarantine officials have approved its use for official plant-quarantine purposes.

The plants listed in table 38 were received, inspected, and held in quarantine for prescribed periods of time prior to release upon orders from the Insular or Federal quarantine officials.

TABLE 38.—*Plants which were held in the plant-quarantine house and released during the year*

Plant	Quantity	Introducing agency	Purpose
Saccharum officinarum	132 seed pieces	Puerto Rico Experiment Station	Sugarcane-mosaic studies.
Do	18 plants	Bureau of Plant Industry	Guayama Variety Garden.
Zoysia tenuifolia	5 flats [1]	Puerto Rico Experiment Station	Lawngrass.
Z. matrella	22 flats [1]	do	Do.
Z. japonica	13 flats [1]	do	Do.
Hibiscus rosa-sinensis	4 cuttings	do	Ornamental plants.
Gossypium spp	2 pounds seed	do	Cotton variety.
Eremochloa ophiuroides	2 bushels stolons	do	Lawngrass.
Livistona rotundifolia	2 plants	do	Ornamental.
Pseudophoenix insignis	do	do	Do.
Pseudophoenix saonae	3 plants	do	Do.
Hyophorbe amaricaulis	do	do	Do.

[1] Increased while in quarantine.

Plant-disease investigations and administration of the plant-quarantine house were conducted by James H. Jensen, plant pathologist and physiologist, who also served as acting director on occasions during the year.

ENTOMOLOGICAL INVESTIGATIONS

The entomological investigations conducted by the station have been in charge of Harold K. Plank, associate entomologist, since October 1, 1936. This work embraced the study of bamboo insects, with particular emphasis on the powder-post beetle, *Dinoderus minutus* (F.), and study and consultation concerning the control of miscellaneous insects occurring on or attacking other crop plants being propagated or used at the station. In addition, observations were continued on the coconut rhinoceros beetle, *Strategus oblongus* (Beauv.), which were initiated by the Bureau of Entomology and Plant Quarantine during the previous fiscal year.

The results of the work on the powder-post beetle and other bamboo insects for convenience in reference are included in the section of this report on bamboo propagation and utilization. The results of the most important observations made on other insects are as follows:

Heavy infestations of Ormenis marginata (Brunnich) on hairy jasmine were controlled by parasitic fungus.

Plants of the hairy jasmine, *Jasminum pubescens*, growing on the station grounds, were heavily infested with the fulgorid vine hopper, *Ormenis marginata* (Brunnich). This hopper is a common species and feeds on a number of other plants in Puerto Rico. It sucks the sap from the twigs and undersides of the leaves and covers them with a characteristic white, waxy secretion in which the young develop. As this insect also produces honeydew the leaves on even moderately infested plants soon become unsightly by reason of a black sooty mold that grows on this honeydew. While little injury, other than a few dead leaves and twigs in the inside of the bushes, was seen, there was considerable blackening of the leaves near the outside by sooty mold.

Examination revealed that nearly half the adult hoppers were attacked by an entomogenous fungus which was determined by Vera K. Charles of the Bureau of Plant Industry as a species of *Isaria*.

Leaf webber infestation on Derris elliptica was not severe this year.

Larvae of what has been called the "bean leaf webber," determined by W. Schaus of the Bureau of Entomology and Plant Quarantine last year as *Lamprosema indicata* (F.), were seen again during December, webbing together the leaves of many of the young *Derris elliptica* plants being propagated at the station. The intensity of the infestation did not appear to be so great as it was a year ago. R. H. Moore, in charge of the insecticidal plant project, stated that he was able to keep the infestation down by hand picking and reported considerable success with this method both in propagation beds and in the field. On large thrifty plants the infestation never seemed to reach any considerable proportion.

This insect has been collected at various times at Mayaguez and several other parts of the island on *Derris elliptica* and other papilionaceous plants such as cowpeas, peas, and lima and other beans. While the larva has been recorded parasitized by *Argyrophylax albincisa* (Wied.), a tachinid fly, none of these parasites were encountered during the present observations.

Skipper larvae found attacking Derris.

Along with a number of common leaf-feeding insects, larvae of a skipper were found in the folded leaves of young *Derris elliptica* plants growing from cuttings in the propagation beds on the station grounds. The adult stage reared from these larvae was identified by J. F. Gates Clarke of the Bureau of Entomology and Plant Quarantine as *Acolastus amyntas* (F.).

This insect has been recorded as feeding on "ventura", *Ichthyomethia piscipula*, one of the Papilionaceae, the same family in which "bucare", *Erythrina* species, belongs. The adult is also recorded as having been taken at Mayaguez and in an orange grove at Manati. While the damage caused was not serious, so far as can be determined the present one is the first record of this insect attacking *Derris*.

Larvae of a tiger moth were destructive to vanilla leaves.

At various times during the past fall and winter small numbers of a dark-brown, bristly caterpillar of the family Arctiidae were seen eating out large pieces of a few leaves on vanilla plants in the propagation house. After numerous failures to rear the adult, this stage was finally obtained and submitted for identification to the Bureau of Entomology and Plant Quarantine. There it was determined by J. F. Gates Clarke as *Ecpantheria icasia* (Cramer). This insect attacks the pods of beans and is a minor pest of other vegetables. It has been previously recorded from various parts of Puerto Rico, including Mayaguez, feeding on the leaves of sweetpotato, orange, banana, *Cissus sicyoides*, *Erythrina micropteryx*, and vanilla.

R. H. Van Zwaluwenburg [5] found *Eremotylus angulatus* Hooker, an ichneumonid parasite of the larva, in Puerto Rico. Although this insect is an open feeder and as such can very likely be effectively controlled by hand picking or by spraying the affected plants with a stomach poison, it is important as a potential pest of vanilla because it feeds on the leaves of bucare, *Erythrina* sp., which is used for living supports for the vines. In this connection it is of interest to mention that Wolcott [6] reported that 2,450 larvae hatched from a single egg cluster found on guava. In the present rearing work two larvae consumed 29 vanilla leaves, each about 4 inches long, in about 1 month while developing from the early first-instar stage to the pupal stage. The great fecundity and voracity of this insect would indicate the advisability of constant vigilance and early control in vanilla plantings, especially in those newly set out on *Erythrina* supports where it is possible for this insect to transfer or largely confine its feeding to vanilla.

Dwarf varieties of coconut palms were but slightly attacked by the rhinoceros beetle.

On June 11 and 12, 1936, a number of dwarf coconut palms that had been received from the Bureau of Plant Industry several years previously were transplanted from a seedbed and field plats on the station grounds at Mayaguez, to field plats on the Ferrer Plantation at Tres Hermanos. These varieties were Green Malay, Red Malay, Yellow Malay, and Bianchi.

[5] VAN ZWALUWENBURG, R. H. NOTES ON THE LIFE HISTORY OF ECPANTHERIA ERIDANUS CRAMER. Insecutor Insectae Menstruus 4: 12–17. 1916.

[6] WOLCOTT, GEORGE N. "INSECTAE BORINQUENSES". A REVISED ANNOTATED CHECK-LIST OF THE INSECTS OF PUERTO RICO. With a host-plant index by José I. Otero. Jour. Agr. Univ. Puerto Rico. 20, 627 pp., illus.. 1936. See p. 417.

Table 39 gives the results of the two examinations made since planting, namely, on August 28, 1936, and January 29, 1937, showing the number of palms found newly attacked by this beetle at each examination.

TABLE 39.—*Rhinoceros beetle attack observed at various times in imported varieties of dwarf coconut palms transplanted from the experiment station grounds, Mayaguez, to the Ferrer Plantation, Tres Hermanos, P. R., June 1936*

Date of examination	"Green" Malay Dwarf, imported under P. I. No. 53497 and Mayaguez Nos. 1878 and 1903		"Red" Malay Dwarf, imported under P. I. No. 53498 and Mayaguez Nos. 1879 and 1904		"Yellow" Malay Dwarf, imported under P. I. No. 53499 and Mayaguez Nos. 1880 and 1905	
	Exposed	Attacked	Exposed	Attacked	Exposed	Attacked
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
June 11, 12, 1936, transplanted	18	1	11	5	22	9
Aug. 28, 1936	[1] 17	1	11	2	22	1
Jan. 29, 1937	[1] 10	0	11	0	[1] 18	0
Total	10	2	11	7	18	10
Percent		20.0		63.6		55.6

[1] Difference between this number and that originally planted signifies the number of palms discarded as dead from other causes and not replanted.

It will be noted that at the time of transplanting a number of palms were already attacked. These palms were then in good condition, all palms dead either from beetle attack or other causes having been discarded. As there were only two palms of the Bianchi variety transplanted, these are not shown in the above table. One palm of this variety was attacked by the beetle between June 12 and August 28.

Although the number of palms involved is too small to permit the drawing of any conclusions as regards the relative susceptibility of the various varieties to rhinoceros beetle attack, it appears that the red and yellow varieties have suffered the most. These data are of interest because this is the only planting of dwarf varieties of coconuts known in Puerto Rico.

Gambusia mosquito-eating fish were liberated in two reservoirs on the station grounds.

The finding of anophelene mosquito larvae in the new Cacaotal Reservoir in Vanilla Valley indicated that this body of water might be devoid of mosquito-eating fish. Consequently on November 20 about 25 small top minnows were taken from the small stream draining the bamboo propagation field north of the station buildings and liberated in this reservoir.

While no mosquito larvae could be seen in the Jagua Reservoir on the Miradero Road, on November 30 this reservoir was also stocked by liberating in it about 20 top minnows from the same source.

The fish used in both cases were determined by J. A. Ramos, assistant biologist of the College of Agriculture and Mechanic Arts of the University of Puerto Rico in Mayaguez, as *Gambusia holbrooki*, a species which, according to Stuart Danforth, biologist of the same institution, occurs in few other places in the island.

Jagua Reservoir was stocked with food fish.

On January 3 four barrels containing 500 channel catfish, *Ameiurus melas*, and 500 bluegill sunfish, *Lepomia incisor*, were received in San Juan through the auspices of J. Adger Smyth, chief of the Division of Ornithology and Pisciculture of the Department of Agriculture and Commerce of Puerto Rico, who personally accompanied the shipment from Baltimore, Md. These were liberated in the Jagua Reservoir on the station grounds the next day, when the temperature of the air was 28°, the surface water 25°, and the water at a depth of 6 feet 24° C. Although only 22 of the catfish and 12 of the bluegills survived the trip and were available for liberation, Mr. Smyth stated that the two species will very likely become established but will require a long time to reproduce and build up into any considerable population.

BIOLOGICAL CONTROL ACTIVITIES

Introduction of beneficial insects is a new activity of station.

The introduction and colonization of beneficial insects in Puerto Rico was initiated by the Bureau of Entomology and Plant Quarantine in July 1935 and continued until September 30, 1936; subsequently it has been continued by this experiment station as a cooperative project with the Bureau of Entomology and Plant Quarantine.

The purpose of the project has been to introduce into Puerto Rico and colonize species of beneficial insects to aid in the control of major insect pests of the island and through their establishment to build up a reservoir from which introductions of needed species can be made to the continent.

In addition to the numbers colonized in the field from original introductions there has also been reared, in the laboratory, a number of these introduced species in order to supplement the original liberations. Continued studies on the recovery and colonization of these introduced beneficial insects will result in the redistribution of established species to new localities in order to expedite their widespread establishment.

A pupal parasite of fruitflies was introduced from Hawaii.

Two shipments of *Dirhinus giffardii* Silv., a pupal parasite of the Mediterranean fruitfly, *Ceratitis capitata* (Wied.), in Hawaii, were received to aid in the control of *Anastrepha* spp. in Puerto Rico. A total of 90 adults was received by air express between January 4 and March 15, of which 88 were alive on arrival. Because of the small numbers available, rather than make immediate liberations of this insect in the field, it was reared in the laboratory; and because of the scarcity of *Anastrepha* puparia at the time it was necessary to try housefly puparia as hosts for such breeding purposes. A total of 306 adults was thus reared from such housefly puparia, all of which were retained as a breeding stock. A large number of fruitfly puparia became available during June and at the close of the year sufficient numbers of the parasite had been reared to start liberations.

Six species of native parasites were found on fruitflies in Puerto Rico.

The following tabulation gives the species of native parasites which were reared from *Anastrepha* spp. collected during this work. These

were determined by specialists in the Bureau of Entomology and Plant Quarantine:

SPECIES OF NATIVE PARASITES REARED FROM ANASTREPHA MOMBINPRAEOPTANS SEIN AND A. SUSPENSA (LOEW) AT MAYAGUEZ, P. R., 1936–37

Anastrepha mombinpraeoptans Seín:	*Anastrepha suspensa* (Loew):
Ashmeadopria sp.	*Eucoila* (*Hexamerocera*) sp.
Eucoila (*Hexamerocera*) sp.	*Ganaspis* sp.
Microbracon sp.	*Opius anastrephae* Viereck.
Opius anastrephae Viereck.	
Zeteticontus sp.	

The species of *Ashmeadopria*, *Microbracon*, and *Zeteticontus* are recorded from the island for the first time in the foregoing tabulation.

The fact that fewer species of parasites were recorded from *Anastrepha suspensa* than *A. mombinpraeoptans* should not be considered as evidence that the same species do not parasitize both species of *Anastrepha;* the collections of *A. mombinpraeoptans* were much larger, and hence a better opportunity was afforded to obtain records of parasitism of this species than of *A. suspensa.*

Opius anastrephae was the only effective native parasite of fruitflies.

The only native parasite which played any important part in the biological control of *Anastrepha mombinpraeoptans* was *Opius anastrephae.* Parasitism by this species as high as 49.9 percent has been recorded. The other parasities were unimportant and were recorded only occasionally.

Anastrepha suspensa was seldom found attacked by any parasites, and the parasitism recorded for all species was less than 1 percent. The apparent difference for this wide variation in parasitism in the two species of *Anastrepha* present in Puerto Rico seems to have been the type of fruit infested by the two species of fruitflies. All of the native parasites have comparatively short ovipositors and the females are unable to reach the fruitfly larvae when they are present in fleshy fruits.

Introduced parasites of sugarcane moth borer have apparently not become established.

During 1935 and 1936 the Bureau of Entomology and Plant Quarantine introduced into Puerto Rico five new species of beneficial insects to combat the sugarcane moth borer, *Diatraea saccharalis* (F.). These parasites were *Ipobracon rimac* Wolcott, *Lydella stabulans* var. *grisescens* Rond., *Metagonistylum minense* Towns., *Theresia claripalpis* (V. d. W.), and *Leskiopalpus diadema* (Wied.).

Collections of *Diatraea saccharalis* larvae were made throughout the cane-cutting season to determine if any of these introduced species had become established. Rearings from the material collected as yet have failed to show the presence of any of these insects.

One native beneficial species was reared from sugarcane moth borer.

The only native parasite reared from *Diatraea saccharalis* larvae was the tachinid fly, *Lixophaga diatraeae* (Towns.). The highest parasitism recorded for this species was 31.9 percent at Hormigueros while the average for all collections was 9.6 percent. In view of the high infestation in cane by the moth borer, which was found to be as high as 86 percent in some fields on the south coast, it can be readily appre-

ciated that on the whole this native parasite plays only a small part in the biological control of the borer. In some localities, however, under certain favorable conditions it is of economic importance.

Bassus stigmaterus parasite of the sugarcane borer was unfavorably affected by drought.

During January 1936 a number of specimens of *Bassus stigmaterus* (Cress.) were collected at Hormigueros parasitizing the sugarcane moth borer, *Diatraea saccharalis*. The parasitism by this species at that time was 4.8 percent. These records in 1936 marked the first recovery of this species since its introduction some years ago. During the early months of 1936 Puerto Rico experienced one of the worst droughts in its history. It was of interest that later collections of *Diatraea* larvae, notably 192 larvae in August 1936 and 210 larvae in March 1937, failed to show the presence of this parasite. These collections were made in the same general area as the January 1936 collections where the above parasitism of 4.8 percent was recorded. S. M. Dohanian, who observed this species in British Guiana in 1936, reported finding it in very wet regions. The San German Valley, in which Hormigueros is located, normally has a high rainfall, but apparently the extreme drought of 1936 had an adverse effect on the population of this beneficial species.

Coconut scale predators introduced from Trinidad are established.

Two species of predatory beetles, *Azya trinitatis* Marsh. and *Cryptognatha nodiceps* Marsh., introduced from Trinidad during 1936 to combat the coconut scale, *Aspidiotus destructor* Sign., have become well established on the island, especially around San Juan, where they were first liberated. The infestation of coconut scale in ornamental plantings in this area has been noticeably reduced by these species. The successful establishment of these two species made possible collections of beetles for distribution to other sections of the island to aid the natural dispersion of these beneficial insects.

Coconut scale predators were shipped to Santo Domingo.

At the request of Juan Gómez-Menor O., entomologist of the Department of Agriculture, Dominican Republic, a shipment of 400 adults of *Azya trinitatis* and 37 of *Cryptognatha nodiceps* was made to his department on May 10. This is the second instance in which predatory beetles have been redistributed from Puerto Rico by this station. In April 1936 a shipment of *Azya trinitatis* and two native coccinellids was made to Florida.

A parasite from Connecticut failed to reproduce on scale insects of bamboo.

On January 16 a shipment of golden oak scale, *Asterolecanium variolosum* (Ratz.), was received from New Haven, Conn., sent by R. C. Brown of the Bureau of Entomology and Plant Quarantine. This scale material contained an encyrtid parasite, *Habrolepis dalmani* (Westw.) which it was planned to try to rear on *Asterolecanium bambusae* (Bdv.) and *A. miliaris* (Bdv.), both of which are serious scale pests of bamboo. The material was doubly caged to prevent the possible escape of the host scale insect and also any secondary parasites which might be present.

A total of 341 specimens of *Habrolepis dalmani* was reared from this golden oak scale material. These parasites were placed in cages

containing bamboo stalks and leaves heavily infested with *Asterolecanium bambusae* and *A. miliaris*. Not a single parasite emerged from these bamboo scales and dissections failed to show any evidence of parasitism.

A parasite of white papaya scale was received from Louisiana.

A shipment of parasitized *Aulacaspis pentagona* (Targ.) was received on April 26 from R. C. Gaines of the Bureau of Entomology and Plant Quarantine at Tallulah, La. *A. pentagona* is the white peach scale of the southern United States which in Puerto Rico severely attacks the papaya, *Carica papaya*, and numerous other cultivated species. The parasite is a small wasp, *Prospaltella berlesei* (How.), which is found in the southern United States but is not known to occur in Puerto Rico. This was the second attempt to establish this species since a previous introduction was tried in 1936.

There emerged 863 specimens of *Prospaltella berlesei* and also a number of other insects which were killed. The material was doubly caged and care taken to prevent the escape of any secondary parasite or undesirable insect species.

Liberations of 823 specimens of *P. berlesei* were made on the experiment station grounds, Mayaguez, during April and May. The liberation was made in a papaya planting heavily infested with scale, but to date recoveries have not been made.

Two beneficial insects parasitic on the pineapple mealybug were received from Hawaii.

The pineapple mealybug, *Pseudococcus brevipes* (Ckll.), is a serious pest of pineapple plants and many requests have been received from growers for information as to the control of this insect. During 1936 two species of parasites were imported from Hawaii. This material was assembled in Hawaii by D. T. Fullaway, of the Board of Commissioners of Agriculture and Forestry, and provided through the courtesy of Walter Carter, of the experiment station of the Pineapple Producers' Cooperative Association, University of Hawaii. These two species, *Hambletonia pseudococcina* Comp. and *Anagyrus coccidivorus* Dozier, had been imported into Hawaii from Central America and South America, and shipments of breeding stock were made to Puerto Rico early in 1937.

Mealybug parasites were reared in the laboratory for liberation.

A method of rearing these parasites in the laboratory was developed by Dr. Carter, and a brief explanation of the technique used follows. A pineapple plant with a young fruit was potted and brought into the laboratory. A celluloid cylinder with muslin ends and side openings for ventilation and entrance was placed about the pineapple fruit. The young fruit was then infested with mealybugs and the parasites were introduced. The method followed here in infesting the fruit was to place within the cage small pieces of a plant infested with mealybugs and permit the mealybugs to crawl on the fruit. Within 4 to 6 weeks the entire fruit was usually well infested with mealybugs.

The rearing work with *Hambletonia pseudococcina* was started on January 6, and since that time 2,927 adults have been reared in the laboratory, and of this number 2,417 were liberated in the pineapple fields of the island.

The rearing work with *Anagyrus coccidivorus* was started May 6, and since that date 588 adults have been reared and 179 adults liberated.

The technique of handling these two species has now become well understood, and extensive breeding of both species is being continued. The average length of time from oviposition to emergence for *Hambletonia pseudococcina*, under laboratory conditions, was 26 days and for *Anagyrus coccidivorus* 21 days. The females of both species were able to oviposit viable eggs immediately upon emergence.

Male specimens of Hambletonia pseudococcina were rarely observed.

While both species of pineapple mealybug parasites produce males, *H. pseudococcina* has been unique in that males were of rare occurrence. Of the 2,927 specimens reared to date only 10 were males. The males were of the same general shape as the females but were black in color as compared with the dark brown of the females. The males mated with the females normally, but from limited observations thus far the fertilized females tended to produce the same wide variation in sex ratio. Since the unfertilized females were able to produce females, the species may be considered parthenogenetic.

In the case of *Anagyrus coccidivorus* the sexes were divided about equally. Of the 588 adults reared, 284 were males and 304 were females. The sexes mated readily in small glass vials shortly after emergence.

Mealybug parasite is apparently successfully established.

Numerous specimens of *Hambletonia pseudococcina* have been recovered from field-collected material at Lajas. These initial recoveries seem to indicate that permanent establishment of this species has been accomplished.

Introduced thrips parasite was reared in the laboratory.

Twelve generations of *Dasyscapus parvipennis* Gahan, the thrips parasite introduced in February 1936 via Trinidad from the Gold Coast, Africa, were reared in the laboratory. A total of 31,901 puparia were reared during this period on the red-banded thrips, *Selenothrips rubrocinctus* (Giard.). Collections of thrips material for this work were made from infested leaves of the tropical almond, *Terminalia catappa*.

This parasite was introduced into Trinidad primarily to aid in the control of *Selenothrips rubrocinctus*, a serious pest of cacao, but it is also reported to parasitize a number of other thrips species including *Thrips tabaci* Lind., the onion thrips.

A total of 26,822 puparia and adults of this thrips parasite, *Dasyscapus parvipennis*, was liberated in various parts of the island. Initial recoveries were made immediately after liberation, but observations thus far do not indicate permanent establishment.

One thousand puparia of Dasyscapus parvipennis were shipped to the continental United States.

On December 11 a shipment of 1,000 puparia was made by airplane from Puerto Rico to Washington, D. C. These puparia were for experimental use at Beltsville, Md., by the Bureau of Entomology and Plant Quarantine. The emergence from these puparia while not counted was reported as very satisfactory by Floyd Smith who handled the material at destination.

Dr. Smith successfully reared this parasite on *Heliothrips haemorrhoidalis* (Bouché) in cages at a temperature of 80° F. His previous unsuccessful breeding trials were held at normal greenhouse temperatures. He concluded from experiments thus far that the parasite requires a higher temperature for optimum development than is usually maintained for the winter growing of most greenhouse crops, and that in general it probably cannot be successfully used for the control of thrips in greenhouses.

Dung-rolling beetles were received from Hawaii.

A shipment of 16 individuals of *Copris incertus* var. *prociduus* (Say) to combat the horn fly of cattle, *Haematobia irritans* (L.), in Puerto Rico was received from Molokai, Hawaii, on October 15. These dung-rolling beetles were shipped by steamer to San Francisco and from there by air express to Puerto Rico. The material was assembled in Hawaii by D. T. Fullaway and O. C. McBride and packed in moist moss. The beetles were in excellent condition and all living on arrival at Mayaguez.

On October 27 a liberation of 276 dung balls containing larvae and pupae of this *Copris*, reared in the laboratory, was made on the property of Russell & Co., Hormigueros. These balls were buried at the edges of a pasture to a depth of 6 inches. On this date and in the same location a liberation of 38 adult beetles of the same species was also made.

Beneficial insects parasitic on the horn fly were received from Hawaii.

A shipment of 33 adults of *Spalangia philippinensis* Fullaway, a hymenopterous parasite of the horn fly, *Haematobia irritans*, was received from Hawaii on January 4. A previous shipment had been received in August, and the breeding work with this species was already under way. These shipments were assembled by D. T. Fullaway.

The puparia used as hosts in the breeding of this parasite were largely those of the housefly, *Musca domestica* L. These puparia were obtained in large numbers by placing infested dung upon wire screens and collecting the full-fed larvae as they left the dung just previous to pupation. A total of 23,046 puparia of the housefly were exposed to parasitism by *S. philippinensis* along with 2,565 puparia of the fruitflies, *Anastrepha* spp., 1,500 puparia of the horn fly, *Haematobia irritans*, and 1,151 of *Sarcophagula* sp. Under these conditions the average length of time from oviposition to emergence for the parasite was 31.9 days.

The emergence from all this material totaled 7,818 adult *Spalangia philippinensis*. Of this number, 6,812 were liberated in 11 different sections of the island to aid in the control of the horn fly of cattle and other fly pests.

Several native parasites were reared from housefly and horn fly puparia.

One native parasite species is of importance in the control of the horn fly, namely, *Spalangia muscidarum* Rich. Parasitism by this species was found to be as high as 30 percent. This parasite is also important in the control of the housefly.

A species of *Ashmeadopria*, apparently undescribed, reared from housefly puparia collected at Hormigueros, was responsible for 10 percent parasitism in some collections.

Specimens of *Pachycrepoideus dubius* Ashm. were often found in collections of housefly puparia, but the percentage of parasitism was always small.

One specimen of *Spalangia drosophilae* Ashm. was also reared from horn fly puparia collected at Lake Guanica.

Two beneficial insects which attack the pink bollworm of cotton were received.

Two shipments of parasites of the pink bollworm, *Pectinophora gossypiella* (Saund.), were received from Presidio, Tex. This material was assembled by A. J. Chapman and L. W. Noble of the Bureau of Entomology and Plant Quarantine. One shipment consisted of 10,247 larvae and pupae of *Exeristes roborator* (F.), a larval parasite of the pink bollworm. From this material there emerged 6,392 adults—3,118 males and 3,274 females.

The liberations of *Exeristes roborator* were made on the south coast, Boqueron, Barrio La Costa, between April 8 and April 16, in heavily infested cotton fields covering about 40 acres. A total of 2,751 males and 2,971 females were liberated in this area. This is a dry area and is an entirely different environment from the locations on the north coast where liberations of this species were made during the past 2 years.

A second shipment consisted of larvae of *Ephestia kuehniella* Zell. parasitized by *Chelonus blackburni* Cam., another parasite of the pink bollworm. The expected emergence from this material was only 20,000 adults; however, actually a total of 46,028 adults of *C. blackburni* were reared. Of this number 42,697 parasites were liberated in May on the south and north coasts of the island in 15 different localities.

Initial recoveries of pink bollworm parasites were made.

Recoveries of both introduced species of pink bollworm parasites, *Exeristes roborator* and *Chelonus blackburni*, were made on the south coast within a few months after liberation. Similar recoveries were made on the north coast in 1936 shortly after liberations were made there, but later collections in both infested cotton and maga, *Montezuma speciosissima*, failed to show any further evidence of these parasite species in that region. The enforced "dead season" for cotton planting is an important factor in the establishment of these parasites, and whether they will be able to survive this period still remains in doubt.

The only native parasite definitely found to be parasitic on the pink bollworm in Puerto Rico was a new species of *Perisierola*, near *nigrifemur* (Ashm.) determined by C. F. W. Muesebeck, of the Bureau of Entomology and Plant Quarantine.

Banana corm weevil predators required years for establishment in Fiji.

During March 1936 the Bureau of Entomology and Plant Quarantine introduced into Puerto Rico from Fiji 568 adults of *Plaesius javanus* Erichson, a predator of the banana corm weevil, *Cosmopolites sordidus* (Germar.). On account of the great economic importance of the weevil numerous inquiries have been received as to the establishment of this predator in the island. The development of this species is being followed closely and continual checks have been made to learn of its progress in order that, if and when it becomes established in the

locations of the original liberation, redistribution to all parts of the island may be made immediately.

This predator from Fiji is a species that had been introduced there from Java. In a letter received at the station from H. W. Jack, Director of Agriculture, Suva, Fiji, the latter states:

> The predators of the banana weevil were not recovered here for at least 5 years after the final introduction but they are now present in great numbers. I have no doubt that the colony sent to you will duly establish itself and I shall be glad to hear from time to time how the position stands.

From the above statement it is probably reasonable to conclude that the presence of the species in Puerto Rico may not be definitely known for several years.

Native wasps were effective in control of the fall armyworm.

W. K. Bailey called attention to the large number of wasps observed hovering about a planting of corn at the experiment station. Observations made on these wasps showed them to be feeding on the fall armyworm, *Laphygma frugiperda* (A. & S.), a serious pest of corn and other crops. Although the corn plants were nearly all damaged by this pest, it was difficult to find any living larvae. The wasps were observed to enter the top of the plants and completely disappear within the central whorl of leaves in search of larvae. When successful in finding a *Laphygma* larva they would emerge, holding the larva with their mandibles and proceed to feed on the body fluids for a number of minutes. They would then fly off, usually carrying a small portion of the body of the larva in their mandibles. Observations showed a number of dead and partially consumed larvae in the leaf whorls.

A few larvae were placed on the outside of a whorl of leaves in order to observe the capture. In no case did the wasps sting the larva. The larva was seized directly by the mandibles and the larval skin readily cut. As the body fluids flowed out the wasps held the larvae with the front legs in a characteristic sitting position and proceeded to feed.

Four species of predatory wasps found thus associated with *Laphygma frugiperda* were determined by G. A. Sandhouse of the Bureau of Entomology and Plant Quarantine. *Polistes crinitus* var. *americanus* (F.) was the most plentiful species; *P. major* Palisot de Beauvois was quite prevalent; *Mischocyttarus phthisicus* (F.) was plentiful; and *Sceliphron caementarium* (Drury) was the least abundant and was not observed actually feeding on *Laphygma* larvae. From the feeding that was observed, it is probable that in places where plentiful the other four wasps played an important part in the control of the fall armyworm.

Larvae of white grub predators were shipped to Mauritius.

At the request of W. R. Thompson, Superintendent, Farnham House Laboratory, The Imperial Institute of Entomology, England, cooperation was provided to assemble in Puerto Rico breeding material of *Pyrophorus luminosus* Illiger, a predator of the white grub, *Phyllophaga* spp., for colonization in Mauritius. These predators were shipped to Dr. Thompson in England, who reshipped them to Mauritius.

In the first shipment various materials were used as packing media in order to determine the optimum conditions under which the preda-

tory larvae could be transported. All of the materials were sterilized with live steam and moistened slightly at the time of packing. The following media were used: Sifted soil, unsifted soil, sand, decayed coconut wood, sand and soil mixed, and moss. By far the best results were obtained with the decayed wood of coconut, *Cocos nucifera*. Dr. Thompson in his early reports recommended that less moisture be used. Later shipments were made in decayed coconut wood without the addition of any moisture, using only that which was present as a result of steam sterilizing, and this practice gave excellent results and maximum survival.

A total of 11,281 *Pyrophorus* larvae were shipped from October 22 to January 28. W. F. Jepson, entomologist of Mauritius, reported that 8,127 of these larvae were dispatched from England. In the last shipment of 1,896 larvae 87.02 percent reached England alive. A high mortality resulted in early shipments due to exposure to cold.

The giant toad has controlled the white grub in the lowlands of the island.

The *Pyrophorus* larvae mentioned above were collected at Cidra, located in the central portion of the island. In this regard it should be noted that the white grubs, *Phyllophaga* spp., have practically disappeared from the lowlands of Puerto Rico as a result of the introduction and colonization by the station some years ago of the giant toad, *Bufo marinus* L. As the toad is not readily adapted to the mountainous regions of the island, the white grubs and their predators are now found in abundance only in these mountainous sections.

K. A. Bartlett, associate entomologist, has been in charge of biological control activities, working in close cooperation with C. P. Clausen, in charge of the Division of Foreign Parasite Introduction of the Bureau of Entomology and Plant Quarantine. The successful development of pest control in several instances in the island by the introduction of natural enemies has been due to this excellent cooperation.

ANIMAL PARASITOLOGY

An ant is the intermediate host of a tapeworm of the chicken.

The ant, *Pheidole fallax jelskii* var. *antillensis* Forel, harbors the intermediate or cystic stage of one of the tapeworms of the *Raillietina* group in the chicken. The specific identity of the ant was made by M. R. Smith, collaborator, Bureau of Entomology and Plant Quarantine. The identity of the tapeworm has not been determined.

The cysts are located in the abdomen of the ant. The number of cysts found in any one ant varied from one to eight or more. From one-third to one-half of the ants in some of the nests located in barnyards and near chicken yards have been found infested with the cysts.

This soil-inhabiting ant is one of the most common in Puerto Rico. It is usually found in populous colonies and the nests are easily recognized by the peculiar entrance holes. The ants can be controlled around and in chicken yards by destroying or poisoning the colonies. The prevention of tapeworm infestation among birds which have a free range by attempting to control the ant would be difficult and imperfect.

A snail acts as a host of the liver fluke of the cat.

The snail, *Subulina octona*, serves as an intermediate host of the liver fluke, *Platynosomum concianum*, of the cat. The snails are readily infested by feeding on the ova of the fluke. Two attempts under controlled conditions to infect kittens with the fluke by feeding infested snails were unsuccessful.

This snail is probably the most common terrestrial species in Puerto Rico. It is a favorable host for several species of animal parasites. Besides the liver fluke of the cat, it has been demonstrated to harbor a small tapeworm of the chicken, *Davainea proglottina*, and the lungworm, *Aelurostrongylus abstrusus*, of the cat. Snails taken in the field have been found infested with parasites other than those mentioned above, the most common and most conspicious of these being a species of *Clinostomum*.

The infective stage of the pig hookworm cannot penetrate unbroken skin.

The life history of the common hookworm, *Globocephalus urosubulatus*, of the pig has been studied. The development of the hookworm from the egg through the larval stages presents nothing unusual except the apparent inability of the infective larvae to penetrate the unbroken skin. Several trials to infest young pigs through the skin have been unsuccessful. The larvae did not penetrate a 2-day-old rat skin by using the cork-ring method originated by Goodey. Apparently the usual and only avenue of infestation of the pig by this worm is through the mouth.

Several species of snails act as intermediate hosts of one of the tapeworms of the chicken.

Feeding trials were made to determine the snail hosts of the tapeworm, *Davainea proglottina*, of the chicken. Infection of chickens by this tapeworm was obtained by feeding the terrestrial snails, *Subulina octona*, *Bulimulus exilis*, and *Varicella impressa terebraeformis*. Negative results were obtained by feeding the snails *Leptinaria lamellata*, *Analcadia striata*, and *Thysanophora euclasta*. This group of snails includes all of the more common species of terrestrial snails at Mayaguez and vicinity. The snails were collected from several different barnyards and chicken runs. The specific identity of the snails was made by H. A. Rehder of the United States National Museum.

Trichomonad abortions occur among cattle in Puerto Rico.

The protozoan, *Trichomonas foetus*, was found in a herd of dairy cattle at Mayaguez. The organism is associated with and apparently produces abortions in cattle. The herd in which the infection was found has reacted negatively to three consecutive tests for infectious abortion. The tests were made by the personnel of the Bureau of Animal Industry.

The protozoa were found in the exudate from the uterus and vagina of two cows which had aborted. It was also demonstrated in the fetal membranes and in the stomach contents of the fetuses. It is suspected that trichomonad abortion is an important disease problem in Puerto Rico. The incidence of this organism should be determined.

These investigations of animal parasites have been carried on by H. L. Van Volkenberg, parasitologist.

CHEMISTRY INVESTIGATIONS

CHANGES PRODUCED BY SULPHUR APPLICATIONS ON THE HYDROGEN-ION CONCENTRATION AND SULPHATE CONTENT OF HIGHLY CALCAREOUS SOILS

Chlorosis-affected sugarcane did not recover following sulphur applications.

During the year field experiments were conducted by the Division of Plant Pathology to determine whether or not the application of sulphur to highly alkaline, calcareous soils on the south coast of Puerto Rico would control sugarcane chlorosis; the division of chemistry cooperated by making the pH determinations of the soil with such treatments. In the course of the experiments it became evident that the application of amounts of sulphur up to 4,000 pounds per acre had not greatly decreased the alkalinity of these soils and hence failed to prevent chlorosis. Studies were therefore begun to learn more concerning the effect of sulphur on such calcareous soils and the amount required to bring them nearer to neutrality. A laboratory experiment was set up using samples of soil from areas which produced diseased or chlorotic sugarcane and from areas which produced healthy sugarcane.

pH determinations of soils were made in sulphur-application experiments.

The samples were taken in both the healthy and chlorotic areas from two different layers, the first layer from the surface to 8 inches in depth and the second layer from 8 to 16 inches in depth. The samples from the first layer of soil in the area producing healthy cane were marked H–1 and those from the second layer H–2. Similarly, the samples from these two layers of soil in the area that produced unhealthy cane were designated U–1 and U–2, respectively. Each of the four samples of soil was air-dried, ground, mixed, and divided into 25 portions weighing 200 grams each. The 100 portions thus obtained were then placed in glass tumblers. The 25 portions of each of the different samples were divided into lots of five; each lot received a treatment with sulphur at one of the following rates per acre: (*a*) 2,000 pounds, (*b*) 4,000 pounds, (*c*) 8,000 pounds, (*d*) 12,000 pounds, and (*x*) no sulphur, as control. The sulphur used in all cases was of identical nature, finely ground commercial sulphur.

The sulphur was thoroughly mixed in each soil sample and sufficient distilled water was added twice weekly to maintain the soil at its optimum moisture content. The samples were incubated at room temperature, the vessels being protected from direct sunlight. The soil in each sample was examined for acidity and sulphate content at intervals of 4 weeks, until the last reading, which was following an interval of 6 weeks, or 22 weeks from the start of the experiment; five successive determinations were thus made from each treatment. Figure 27 shows the effect of these sulphur applications in increasing quantities on the alkalinity of sample H–1 or the 0–8-inch layer and H–2 or the 8–16-inch layer, both of healthy soils, as well as U–1 or the 0–8-inch layer and U–2 or the 8–16-inch layer, both these latter of diseased soils.

Sulphur applications caused small change in soil reaction.

From the results obtained, as shown in figure 27, it may be seen that in every series there was a continuous decrease in the pH of the soil with increase in the amount of sulphur applied, even though a

greater difference might have been expected with the larger sulphur applications; this decrease in pH continued throughout the length of the experiment, but the greatest decrease was produced during the first 4 to 8 weeks. As was to be expected, the sample from the surface layer of the soil which produced healthy cane, series H–1, showed an

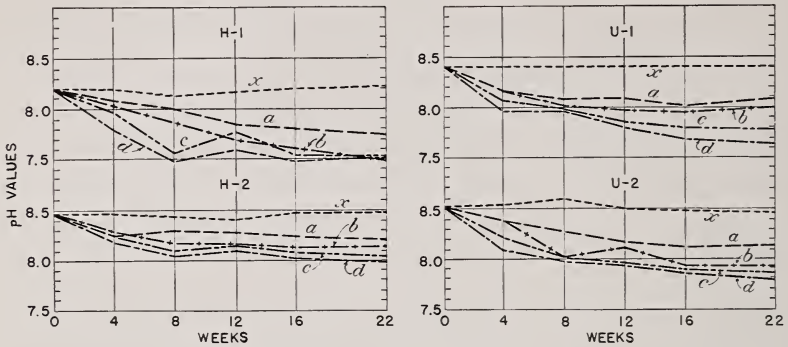

FIGURE 27.—Changes in pH values of samples of highly calcareous soils by sulphur treatments: H–1, Soils 0–8 inches deep which produced healthy cane; H–2, soils 8–16 inches deep which produced healthy cane; U–1, soils 0–8 inches deep which produced chlorotic cane; U–2, soils 8–16 inches deep which produced chlorotic cane; *x*, untreated soils; *a*, 2,000; *b*, 4,000; *c*, 8,000; *d*, 12,000 pounds sulphur per acre.

initial pH lower than that of the soil producing chlorotic cane, series U–1. The initial pH of the subsoil, series H–2 and U–2, were much the same, but both showed higher alkalinity than the surface soils.

The essential conclusion was that with the highest rate of sulphur per acre, 12,000 pounds, the pH did not reach neutral; in fact in no case was it lowered to less than 7.5.

Sulphur applications increased gypsum formation.

The small decrease in the alkaline reaction of the soil solution found in the above laboratory experiment made it desirable to determine the rate of oxidation of the sulphur applied to the soil samples. The

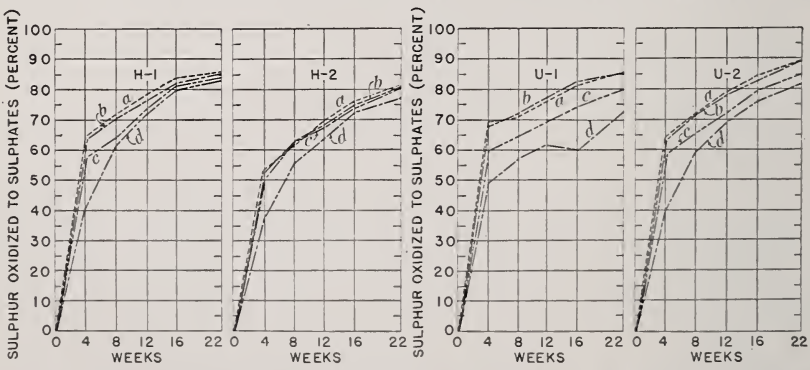

FIGURE 28.—Calculated percentages of applied sulphur oxidized to sulphates. Symbols same as for figure 27.

sulphate content of the samples was taken as an index of the degree of sulphur oxidation and was calculated on two bases, namely, as pounds of sulphur oxidized to sulphates per acre, and the percentages of the sulphur applied which oxidized to sulphates. These results appear in figure 28 and table 40.

TABLE 40.—*Calculated amounts of sulphur oxidized per acre, based on sulphate determinations*

Symbol	Sulphur per acre	Sulphur oxidized to sulphates, per acre, at end of—					Sulphur oxidized to sulphates, at end of—				
		4 weeks	8 weeks	12 weeks	16 weeks	22 weeks	4 weeks	8 weeks	12 weeks	16 weeks	22 weeks
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
H–1 *a*	2,000	1,294	1,438	1,568	1,668	1,724	64.72	71.90	78.40	83.41	86.22
H–1 *b*	4,000	2,552	2,812	3,056	3,294	3,432	63.80	70.32	76.40	82.35	85.80
H–1 *c*	8,000	4,624	5,124	5,872	6,517	6,762	57.80	64.05	73.40	81.47	84.53
H–1 *d*	12,000	4,814	7,221	8,696	9,724	10,034	40.12	60.18	72.46	81.04	83.62
H–2 *a*	2,000	1,062	1,220	1,394	1,516	1,602	53.12	61.00	69.72	75.80	80.12
H–2 *b*	4,000	2,086	2,483	2,713	2,982	3,200	52.17	62.08	67.83	74.55	80.00
H–2 *c*	8,000	4,067	4,883	5,368	5,880	6,308	50.84	61.04	67.10	73.50	78.85
H–2 *d*	12,000	4,490	6,648	7,588	8,648	9,074	37.42	55.40	63.24	72.07	75.62
U–1 *a*	2,000	1,376	1,433	1,542	1,642	1,720	68.80	71.65	77.10	82.12	86.00
U–1 *b*	4,000	2,718	2.872	3,140	3,320	3,486	67.95	71.80	78.50	83.00	85.90
U–1 *c*	8,000	4,788	5,152	5,568	5,944	6,465	59.86	64.40	69.60	74.30	80.82
U–1 *d*	12,000	5,984	6,890	7,428	7,274	8,730	49.87	57.42	61.90	60.62	72.75
U–2 *a*	2,000	1,300	1,439	1,567	1,694	1,775	65.00	71.98	78.39	84.71	88.75
U–2 *b*	4,000	2,560	2,872	3,112	3,293	3,516	64.00	71.80	77.82	82.33	87.92
U–2 *c*	8,000	4,620	5,225	5,760	6,318	6,772	57.75	65.32	72.00	78.98	84.65
U–2 *d*	12,000	4,782	7,071	8,198	9,063	9,840	39.85	58.93	68.32	75.53	82.00

Whether the amounts of sulphates formed or the ratio of sulphates to total applied sulphur is studied, it is readily seen that considerable increase in sulphates occurred in all samples during the first 4 weeks. While this increase was continuous up to the twenty-second week, the highest rate of sulphate formation was obtained during the first 4 to 8 weeks. The curve of sulphur oxidation had become somewhat flattened 22 weeks after the sulphur had been added to the surface soils, but was continuing at a considerable rate in the subsoils. In general, the highest percentage rate of sulphate formation was obtained where the sulphur application rate was only 2,000 pounds per acre; however, other larger applications of sulphur yielded percentage oxidation rates almost as favorable. Thus, while there was some decrease in the percentage rates of sulphate formation with the increase in the rate of application of sulphur, the amount of sulphates formed was naturally much larger in the higher than in the lower applications. The determinations showed that, with 72 to 83 percent of the applied sulphur oxidized into sulphates, the heavy expensive applications of 12,000 pounds of sulphur per acre did not reduce the alkalinity of these soils to neutrality. The conclusion must necessarily be that attempts to control chlorosis of sugarcane by applications of sulphur to these calcareous soils of high alkalinity at the present time would be considered uneconomical.

Sulphur applications improved water percolation in soil.

In making the sulphate determinations an actual test of the rate of percolation of water through the soil was not made, but under 5 inches of vacuum considerable differences were observed in filtration of the water through the soil. The lowest rate of water filtration was obtained with the untreated soil, this rate increasing with the increases in sulphur applications. The highest rate of filtration was obtained with the highest application of sulphur.

Sulphur applications increased liberation of carbon dioxide.

During these tests of sulphur oxidation the questions arose as to how much carbon dioxide was liberated and as to the possible formation of calcium bicarbonate by the sulphur applications. The liberation of carbon dioxide was observed over a 2-week period as follows: Five additional 200-gram portions of soil from the chlorotic area were given the same sulphur and water treatments as in the previous tests, and then placed in 500-cubic centimeter Erlenmeyer flasks. Air was drawn through the flasks from an automobile inner tube inflated with air that had first been freed from carbon dioxide gas by passing it through absorption towers. The gases liberated from the soils were washed in standard sodium hydroxide solution to absorb any carbon dioxide produced.

On precipitation with barium chloride no attempt was made to weigh the barium carbonate precipitated, but a rough volumetric comparison was made of the precipitates after they had been placed in tubes and centrifuged for 3 minutes. The lowest quantity of barium carbonate was obtained from the extract from the untreated soil, the quantity rising consistently with the gain in sulphur treatments, until the highest amount was obtained with the highest sulphur treatment.

In this connection it is of interest to note that the soil extracts prepared for the previous sulphate determinations were water clear, but on undertaking evaporation carbon dioxide bubbles were given off and a turbidity developed throughout the liquid; apparently the calcium at first was present as the more soluble bicarbonate, but with the loss of CO_2 on heating the less soluble carbonate was left. The addition of hydrochloric acid then increased gas formation showing decomposition of carbonates. Water extractions showed small amounts of carbonates and some bicarbonates for untreated soils, while those from sulphur-treated soils showed only bicarbonates. The extracts from the sulphur-treated soils also showed acid reaction toward phenolphthalein when cool, but on heating, carbon dioxide was liberated and the pink color increased in density. This color increased on boiling at the same time that the extract grew turbid through formation of calcium carbonate.

Theoretical amounts of limestone neutralized were calculated.

Assuming that such high percentages of applied sulphur as those observed in the above sulphur-application experiments should be oxidized in 5 months, it is possible to make a rough calculation of the limestone neutralized and the gypsum formed during the 22 weeks of the experiment. Theoretically, 32 pounds of sulphur will oxidize into 98 pounds of sulphuric acid, and in uniting with 100 pounds of limestone will form 172 pounds of gypsum. Table 41 shows the treatments given the various soil samples, and the calculated amounts of sulphur oxidized, possible limestone neutralized, and gypsum formed at the end of 22 weeks.

In conclusion it can be stated that the soils upon which sugarcane becomes severely chlorotic on the south coast of Puerto Rico are highly calcareous. The surface soils of such areas had a pH of 8.4, while the subsoils were more alkaline and reached a pH of 8.5. Contiguous areas which produced normal, green cane and profitable crops had a lower pH in the surface soil, 8.2, but the subsoils of such healthy areas had an alkalinity almost as high as that of the chlorotic areas.

TABLE 41.—*Calculated amounts of sulphur oxidized, calcium carbonate neutralized, and calcium sulphate at end of experiment*

Sulphur per acre	Symbol	Soil from nonchlorotic areas			Symbol	Soil from chlorotic areas		
		Sulphur oxidized per acre	$CaCO_3$ neutralized per acre	$CaSO_4.2H_2O$ formed per acre		Sulphur oxidized per acre	$CaCO_3$ neutralized per acre	$CaSO_4.2H_2O$ formed per acre
Pounds		*Pounds*	*Pounds*	*Pounds*		*Pounds*	*Pounds*	*Pounds*
2,000	H–1 *a*	1,724	5,387	9,266	U–1 *a*	1,720	5,375	9,245
4,000	H–1 *b*	3,432	10,726	18,447	U–1 *b*	3,486	10,893	18,737
8,000	H–1 *c*	6,762	21,131	36,345	U–1 *c*	6,465	20,203	34,749
12,000	H–1 *d*	10,034	31,356	53,932	U–1 *d*	8,730	27,281	46,923
2,000	H–2 *a*	1,602	5,006	8,610	U–2 *a*	1,775	5,546	9,540
4,000	H–2 *b*	3,200	10,000	17,200	U–2 *b*	3,516	10,987	18,898
8,000	H–2 *c*	6,308	19,712	33,905	U–2 *c*	6,772	21,162	36,399
12,000	H–2 *d*	9,074	28,356	48,772	U–2 *d*	9,840	30,750	52,890

Experimental applications of sulphur reduced the alkalinity of the surface soils of the chlorotic areas to pH 7.7 and in the subsoils to pH 7.8, two points lower than the pH of the subsoils in contiguous areas producing normal, green cane; yet similar applications in field experiments did not cause recovery of chlorotic cane in such areas.

There was an increased liberation of carbon dioxide and an improved ease of penetration of the soil by water as the rate of application of sulphur increased, which indicated an increased decomposition of the limestone and a corresponding formation of gypsum in the treated soils.

Sulphur applications to these soils constituted an expensive chlorosis control.

As measured by sulphate determinations in the sulphur-treated soil samples, applications of 2,000 pounds of sulphur per acre oxidized more efficiently than larger applications of 8,000 and 12,000 pounds per acre. However, as high as 83.62 percent of the sulphur became oxidized when it was applied at the rate of 12,000 pounds per acre. Such high rates of sulphur application without neutralizing the soil alkalinity do not seem economic for chlorosis treatment at the present time. The undecomposed calcium carbonates in the chlorotic soils were apparently in masses or concentrations too great and required sulphur applications too large to bring the soil reaction near neutrality, to compensate for the cost of the sulphur.

Analyses of mango fruits were extended.

In the last annual report some analyses were given of the juices and pulp of representative varieties of mangoes in the extensive collection maintained at the station. During the past year these analyses were extended to include information on the comparative ash content, proteins present, and fiber. The results of analyses are shown in table 42.

The results of the pH determinations this year from pulp samples were in some degree of conformity with results obtained from extracted juice samples recorded in the previous annual report. Concerning total titratable acids the Singapore, Alphonse seedling, Amini, Mullgoba, and Sandersha varieties all showed high readings. The Concord, Sufaida, Madras, Faizan, and Bulbulchasm seedling all showed low total titratable acids. The varieties Martinique, Haden, Cambodiana, Itamaraca, and Divine also had comparatively low titratable

acids; in this group would probably be contained the varieties in the greatest demand for table quality. The factor of total titratable acids, even more than the pH, seems to have great importance in the possibilities of canning and dehydrating mangoes.

TABLE 42.—*Analyses of pulp of different varieties of mangoes at the experiment station* [1]

Variety	Moisture	pH	NaOH, N/5, per 100 grams	Reducing sugar	Sucrose	Fiber	Ash, crude	Protein [2]
	Percent		*Cubic centimeters*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Martinique	78.02	4.92	20.2	2.26	13.05	0.53	0.57	0.67
Haden	84.93	5.04	22.6	3.16	8.25	.45	.36	.52
Cambodiana	82.30	4.29	20.9	3.30	10.35	.38	.39	.54
Bulbulchasm	82.60	4.50	27.9	2.45	10.54	.42	.41	.44
Bulbulchasm seedling	84.92	4.75	10.9	3.36	7.52	.39	.36	.34
Alphonse seedling	83.70	3.95	44.8	3.25	8.40	.47	.47	.52
Amini	83.15	4.00	38.0	1.83	11.03	.46	.39	.53
Madras	80.84	4.80	13.0	4.05	10.67	.51	.37	.51
Jamshade	81.80	4.28	29.3	2.28	14.00	.42	.40	.78
Itamaraca	83.07	5.00	20.9	2.67	9.79	.45	.35	.34
Sufaida	83.15	5.24	15.3	3.15	9.85	.43	.40	.51
Mullgoa	76.94	4.42	31.5	2.30	14.86	.58	.60	.57
Mullgoba	72.80	4.02	38.7	3.54	16.60	.66	.68	.69
Concord	78.76	5.08	13.3	3.76	12.73	.52	.61	.53
Do	78.09	4.93	16.3	3.46	13.50	.55	.62	.54
Fajri Long	81.98	3.82	36.0	3.45	9.52	.48	.41	.56
Faizan	85.00	4.51	15.9	3.60	7.73	.37	.39	.32
Singapore	76.40	3.57	76.1	3.37	12.50	.59	.41	.59
Divine	84.80	4.32	23.7	2.92	7.30	.42	.57	.57
Totafari	85.25	3.94	30.9	3.00	9.50	.47	.35	.50
Sandersha	82.88	3.60	41.7	2.35	6.70	.49	.32	.48

[1] Percentages are on the basis of fresh weights.
[2] Calculated by multiplying nitrogen content by 6.25.

In none of the varieties examined was the fiber content sufficiently high to create an unfavorable consumer reaction. The moisture contents of the fruits of all varieties in the test were comparatively uniform.

The foregoing analyses were obtained from composited samples containing at least 15 fruits of each variety.

Because of the different ripening periods of the varieties, the analyses were made at different times, but the fruits were picked with the idea of obtaining as nearly identical degrees of ripeness as possible.

The foregoing investigations have been carried on by J. O. Carrero, assistant chemist, who has also cooperated with other divisions of the experiment station and other agencies of the Federal and Insular Governments in many routine analyses.

BIOMETRIC SERVICE AND RESEARCH

Biometric service was provided for all station experimental activities.

The projected outlines for all experiments at the station were reviewed in this division before being undertaken in the field or laboratory in order to insure that the proper replications, sampling, and randomization were secured. On the completion of experiments, results have been referred to this division for biometric analysis. The value of such consultation has not only been to determine the statistical significance of the results but possible fruitless efforts have been minimized, thus securing the greatest possible experimental returns for the investment in the station activities.

Agronomic experiments on corn spacing were completed.

In addition to the foregoing service activities, this division provided leadership in agronomic experiments with sweet corn. During the year two experiments were completed to determine the optimum spacing for USDA–34 sweet corn under western Puerto Rican conditions. A detailed experiment testing the fertilizer requirements of this sweet corn under lowland field conditions at the experiment station was also completed.

The biometric service continued in charge of A. N. Watson, biometrician and plant physiologist.

WORK OF THE CORRELATING COMMITTEE

The correlating committee continues as a valuable adjunct to the agricultural agencies of the island.

It will be recalled that a committee, designated the correlating committee and composed of the leaders of the various agricultural institutions represented in Puerto Rico, was organized in 1935 to coordinate the activities of these institutions, to avoid duplication and competition in work undertaken, and to insure that no important activity was overlooked.

While there have been but few meetings of this committee during the year, sufficient have been held to serve the purpose for which it was formed. All of the members have found themselves so heavily burdened with routine and other pressing duties that it has been difficult to find time for many meetings, although it is probable that time devoted to such meetings could not be better invested in any other activity.

COOPERATION WITH THE PUERTO RICO RECONSTRUCTION ADMINISTRATION

Camp labor was devoted to soil conservation and new agricultural crops.

At the beginning of the fiscal year the Puerto Rico Reconstruction Administration entered into an agreement with the experiment station to place one of its reconstruction camps on the Las Mesas property of the station. These reconstruction camps were created not only to give employment to agricultural labor but to provide education and discipline as well. The site selected was at an elevation of approximately 1,000 feet, with temperatures perceptibly lower than at sea level, pleasant air movement, and a view of the sparkling, blue Caribbean Sea and Mona Passage. The camp was opened on September 6.

The direction of the projects upon which the labor was employed was assigned to the director of the experiment station. The projects selected and approved by the administrator of the Reconstruction Administration were principally soil-erosion control projects and the propagation of economic plants new to the island, which had possibilities for the creation of new industries and would aid in economic reconstruction.

The activities of the men on various work projects have been mentioned throughout this report, being of outstanding value in the winter-vegetable project, bamboo propagation, extension of improved mango varieties, vanilla investigations and propagation, flood control,

and soil-erosion prevention. Approximately 180 men were used for these projects from September 6 until June 30.

Reconstruction camp yielded high returns on investment.

The administration of the camp, its mess hall, dormitories, sanitation, discipline, and education were directed by the Reconstruction Administration. It is a pleasure to record the high type of cooperation furnished by the Reconstruction Administration; the returns on the investment in this camp, not only in the development of agricultural projects but also in educational accomplishments, would seem to have been at least equal to most other investments in government activities.

During the year the Col. Raul Esteves silver trophy, presented to the reconstruction camp maintaining highest standards of morale, discipline, sanitation, and project accomplishments, was awarded to the Las Mesas camp.

COOPERATION WITH AGENCIES OF THE INSULAR GOVERNMENT

Governor has supported search for new crops.

Governor Blanton Winship has frequently visited the experiment station and kept in close contact with its activities, supporting in particular the investigations leading to the establishment of new crops. He has not only encouraged the projects by his intimate knowledge of them but also has frequently contributed aid from agencies of the insular government.

The Commissioner of Agriculture and Commerce has contributed materials and personnel for some of the activities of the experiment station. The interchange of materials and library resources with the Department of Agriculture and Commerce of Puerto Rico has been a great asset.

The cooperation with the experiment station of the University of Puerto Rico has continued successfully as in previous years. Interchange of planting materials has been particularly helpful, and the association of personnel has been valuable and can be profitably increased.

A spring and contiguous land on the Las Mesas property was made available as a source of water supply for the Tuberculosis Sanitarium of the Insular Department of Public Health.

APPROPRIATION BY THE LEGISLATURE OF PUERTO RICO

Funds were allotted for investigations of vanilla, spice, and perfume plants.

During the year the legislature of Puerto Rico made an appropriation of $18,000 per annum for this experiment station, to be devoted to investigations having as their objectives the establishment of industries for vanilla production and processing, the production of perfume and other essential oils, and the production and processing of spices. The bill was passed by both houses of the Legislature, approved by the Governor, and funds become available for these activities on July 1 of the fiscal year 1937–38.

Appreciation is expressed to the Legislature of Puerto Rico for this additional indication of confidence in the experiment station.

COOPERATION WITH OTHER AGENCIES OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

Department services are succeeding in widely diverse fields.

During the year the Forest Service issued forestry permits to the experiment station for the utilization of small land areas for the adaptability tests with quinine plants. An agreement was also completed under which 15 acres of land of the experiment station are made available to the Forest Service for forest nurseries.

The experiment station has made land available to the Bureau of Animal Industry for a cattle-dipping tank and also has made available laboratory space for an entomologist working on tick problems. Pasture space has also been made available for experimental animals.

Extensive laboratory space, experimental materials, garage and storage space, and a residence have been made available to the Bureau of Entomology and Plant Quarantine.

Extensive office and laboratory space, field facilities and equipment, and a residence have been made available to the Soil Conservation Service.

It is gratifying that the experiment station could have contributed in some measure to the success of the work which these agencies of the Department of Agriculture are achieving.

IMPROVEMENTS IN PROPERTY

Las Mesas property has been made productive.

Due to the labor made available by the Reconstruction Administration a considerable part of the hilly areas of the Las Mesas property has been developed into productive land by the use of mangum and bench terraces. As the land has been terraced it has been put into experimental use, including adaptation tests of newly introduced crop plants. Approximately 800 meters of roadway were graded along the southern border of the property, which was subsequently macadamized and asphalted by the Insular Department of the Interior and made available for public use. In addition, 500 meters of farm road were laid out at Las Mesas reaching a previously inaccessible part of the property which now is available for cultivation and experimentation.

On the 80 acres of the experiment station known as Las Ochenta, as a result of the agreement with the Reconstruction Administration, some 15 acres were placed under mangum terraces and an additional 10 acres in bench terraces. Six hundred meters of farm roadway were laid and surfaced with gravel.

On the lowlands of the experiment station 3 acres devoted to plant-introduction gardens were terraced. The level south fields were tilled in such a way as to provide drainage. The bamboo and mango nurseries have been developed to a point where extensive distributions to other agencies of the Insular and Federal Governments are now possible. Parts of the roadway system of the experiment station were asphalted.

PUBLICATIONS

System of monthly reports was continued.

In 1935 the policy was adopted of preparing monthly reports to the Chief of the Office of Experiment Stations which would list the accomplishments during the month. It was found that the material in these

monthly reports attracted the interest of some of the local planters as well as the personnel in similar activities at other experiment stations and in the bureaus of the Department of Agriculture. During the past year, therefore, the policy of mimeographing these monthly reports was adopted and an edition of 60 to 80 copies is now prepared each month.

"Agricultural Notes" is issued in both English and Spanish.

During the year there were prepared eight numbers of the mimeographed publication, Agricultural Notes, of the experiment station. This publication is issued in both English and Spanish; the English edition has a distribution of 1,000 copies and the Spanish, 1,200 copies. Extracts from the Spanish edition have frequently been given wider circulation in the island newspapers.

The subject matter in the eight numbers issued during the year was as follows:

No. 72. The Mosquitoes of Puerto Rico and their Relation to Human Welfare, by George S. Tulloch, associate entomologist, Division of Insects Affecting Man and Animals, Bureau of Entomology and Plant Quarantine.

No. 73. Experiments in the Treatment of Poultry Parasites in Puerto Rico, by Willard H. Wright, associate parasitologist, Zoological Division, Bureau of Animal Industry.

No. 74. The Effects of Natural Factors, Rain and Sun, on Survival of Eggs and Larvae of Animal Parasites under Tropical Conditions, by Lloyd A. Spindler, assistant zoologist, Zoological Division, Bureau of Animal Industry.

No. 75. The Introduction and Colonization in Puerto Rico of Beneficial Insects, by Kenneth A. Bartlett, assistant entomologist, Division of Foreign Parasite Introduction, Bureau of Entomology and Plant Quarantine.

No. 76. The Search in the American Tropics for Beneficial Insects for Introduction into Puerto Rico, by S. M. Dohanian, Bureau of Entomology and Plant Quarantine.

No. 77. The Introduction and Colonization in Puerto Rico of Beneficial Insects Parasitic on the Pink Bollworm of Cotton, by Kenneth A. Bartlett, assistant entomologist, Division of Foreign Parasite Introduction, Bureau of Entomology and Plant Quarantine.

No. 78. The Introduction and Colonization in Puerto Rico of Beneficial Insects Parasitic on the Sugarcane Moth Borer, by Kenneth A. Bartlett, assistant entomologist, Division of Foreign Parasite Introduction, Bureau of Entomology and Plant Quarantine.

No. 79. The Introduction from Fiji into Puerto Rico of a Predator of the Banana Corm Weevil, by Kenneth A. Bartlett, assistant entomologist, Division of Foreign Parasite Introduction, Bureau of Entomology and Plant Quarantine.

Annual Report has been issued in Spanish and English.

The annual report of the experiment station for 1935 was translated into Spanish and printed, being issued during the fiscal year under review. The Spanish edition increased the number of readers of the report possibly 100 percent. This was the first instance in the history of the station that a Spanish edition of the annual report was made available to the large percentage of Spanish-speaking farmers of the island.

CHANGES IN PERSONNEL

Few changes in personnel occurred during the year.

There have been few changes in the personnel since the beginning of the fiscal year. In August R. L. Davis, agronomist, transferred to the Soil Conservation Service. In February, Jorge Rodríguez Iñigo, under scientific aide, resigned to accept a position as professor

of agronomy in the Government agricultural school at Maracay, Venezuela.

On October 1 Harold K. Plank transferred from the Bureau of Entomology and Plant Quarantine, Department of Agriculture, to assume the position of associate entomologist at the station, specializing in the insects of bamboo and having joint authority with the plant pathologist of the station over the plant-quarantine house. Also on October 1 Kenneth A. Bartlett transferred from the Bureau of Entomology and Plant Quarantine to assume the position of associate entomologist specializing in biological control of crop pests. In both of these activities the work is carried forward under a cooperative agreement with the Bureau of Entomology and Plant Quarantine.

Due to the gradual diminution of funds from the processing taxes collected on the sale of Puerto Rican sugar which were allocated to the experiment station, no reappointments were made in the field personnel as vacancies occurred, with the result that the number of field workers was reduced considerably during the year.

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